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DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES
HUGH M. SMITH, Commissioner

SOME CONSIDERATIONS CONCERNING THE SALTING OF FISH

By DONALD K. TRESSLER
Temporary Assistant, Division of Fishery Industries

APPENDIX V TO THE REPORT OF THE U. S. COMMISSIONER OF FISHERIES FOR 1919

Bureau of Fisheries Document No. 884

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CONTENTS.

SOME CONSIDERATIONS CONCERNING THE SALTING OF FISH.[a]

By DONALD K. TRESSLER, *Temporary Assisant, Division of Fishery Industries.*

Contribution from the Fishery Products Laboratory, Washington, D. C.

INTRODUCTION.

THE NEED FOR EXPERIMENTAL WORK.

Although fish have been preserved with salt since prehistoric times, little experimental work has been done with the view of improving the existing methods. The fisherman who salts his own catches of fish or who cooperates with his neighbors in salting fish has neither the time nor the money to experiment that he may improve his product or save labor and waste products. With a few exceptions, the fishing industry has not attracted large capital for extensive operations. It has not been exploited, therefore, as has the meat-packing industry.

Much work has been done in the hatching of fish eggs, stocking streams and lakes, and increasing the aquatic life of this country generally. But until recently little had been done to conserve the fish after being taken or to utilize as food fish which had hitherto been neglected. Little of the river herring, sea trout, Spanish mackerel, kingfish, sea bass, scup, and drumfish in our southern waters had been utilized until within recent years, when refrigerator cars and cold-storage plants came into use.

It required the stimulus of the enormous demand for food caused by the great world war to awaken an interest in fish salting and to arouse a demand for better methods. It became apparent that if the methods of salting fish could be improved so that fish might be salted with safety during hot weather in any warm climate the food-fish supply of the United States would be greatly augmented.

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[a] This work was undertaken in cooperation with the National Research Council, Council of National Defense, and was at first conducted in the laboratories of Johns Hopkins University, where the author had the benefit of the advice and direction of Prof. B. E. Livingston, department of plant physiology, and Prof. E. V. McCollum, School of Hygiene and Public Health. He is also indebted to Prof. J. J. Abel, of the department of pharmacology of the same university, for the use of his laboratory for the conduct of part of this work.

The results achieved, the conclusions reached, and the recommendations made in this paper have their origin in experiments done on a small scale and are not to be taken as having been proved by commercial practice.

There is a lamentable lack of control over the salt-fish product produced in any plant. In some places the standard of quality is a white, colorless fish. Yet in those localities it is doubtful whether the fish salters understand the factors controlling whiteness. In other localities a very hard, rigid fish is desired. In such regions there is a great demand for Turks Island salt, for it is quite generally understood that this salt produces a hard fish, although very few understand why. Before this experimental work had been followed two weeks the experimenter learned that the qualities of the finished product, such as color and hardness, could be controlled entirely. This alone made the work worth while.

It has long been known that it is exceedingly difficult to salt fish in the ordinary way during hot weather, and few attempt it. Apparently no one had tried to find out why fish spoil so quickly while being salted during the summer.

For centuries fish have been cured either in brine or in dry salt without the addition of brine. There has been much discussion concerning the value of the two methods. It was, therefore, worth while to determine the relative merits of the two methods of applying salt to fish, even though no information relevant to the problem under consideration should be obtained.

The inexactness of the present methods has been pointed out to show the need for such experimental work as is reported in this paper. Correct interpretations of experimental work should lead to more exact procedure in salting fish. A more uniform product should be obtained. The results of the experimental work should explain the reason for some of the methods in use to-day. The consideration of the scientific aspect of fish salting should bring forth a spirit of research for better salt fish. There should be a demand for high standards for salted fish. At present in some parts of the country the salt-fish buyers have practically no standards for estimating the quality of the salt-fish product. This is in part because of the difficulty in estimating differences in quality of salt fish.

At the present time (summer of 1919) the price of salt river herring is very low. This is chiefly because the quality of salted herring sold during the past few years has been so poor. The salt river herring on the market has a very strong "wild-game" taste. If certain precautions were taken, this could be entirely avoided. The resultant product would then be of much better quality than that to which the public is accustomed. It is doubtful if a better price could be obtained for salt river herring under present conditions. If higher standards were demanded, however, it should sell for a higher price.

In North Carolina and Virginia the buying public has become so accustomed to purchasing very hard, dry fish that soft fish in brine will not sell, although it may be better in quality. There is little ground for the argument that dry, hard fish is of greater culinary value. On the other hand, without investigation it would seem reasonable that a wet, soft fish would be more palatable when cooked than a fish "as hard as a board."

Most fish salters are aware of the fact that they must not store their fish in hot places during the summer months; yet no attempt has been made to determine the best conditions for storing salted fish. Fish have been stored both dry ("tight packed," packed in layers

with solar salt between layers of fish) and in brine (pickle); yet no investigation has been carried out to show which of these two methods is the better. The "tight-pack" method is almost universally used in the South, whereas in the North fish, with the exception of cod, haddock, cusk, and pollock, are just as universally stored in brine.

Much may be done to improve both the methods of salting and of storing fish. If better methods were used, salted fish, even the "common herring," would regain its place in public favor. The fish salter would gain immensely thereby, for as the quality improves so will the demand. It is hoped that this work may be the beginning of a movement looking toward a better salted-fish product; that it may encourage the fish salter to control his product and produce a fish of the best possible quality. A proper understanding of the factors affecting the product will surely lead toward the improvement of methods.

PRESENT COMMERCIAL METHODS OF SALTING FISH.

The methods of salting fish in use to-day vary greatly in different localities. The writer found, in going from one fish-salting plant to another, that many fish salters were not familiar with all of the methods of salting fish. It is wise, therefore, to give a brief description of the methods in use in various parts of the country. This will make clear the reasons for the procedure followed in the experimental work. There may also be a better understanding of these different methods, and if they are correctly understood the fundamental principles of salting fish will be clear to the reader.

In this work no mention is made of the mechanical details of cleaning, hauling, lifting, or drying fish. Attention is given to only the important points which affect the quality of the finished product. The writer has visited five fish-salting centers and has observed the methods employed. The procedure followed in salting fish in these places will be described briefly. No attempt has been made to include all of the different processes or the procedure for all varieties of fish. The description merely includes the most important methods and the general procedure.

GLOUCESTER, MASS.

In Gloucester the business of salting fish is very extensive. It is characterized by greater organization and larger companies than elsewhere. The reason for the organization is to be found in the large number of fish caught in that vicinity and in the continuity of the catches. Fish are brought into Gloucester in large quantities every working-day of the year. Employees may, therefore, be hired for the entire year and the plants worked on a larger scale than elsewhere.

The cod, haddock, cusk, and pollock are caught together and are salted in the same general way. When they are unloaded from the vessels, the fish are sorted as to kind and size. During the cold months these fish are salted either in kenches (regular piles or layers of fish) or butts (very large barrels, of about 300 gallons capacity). In the warmer months all are salted in butts, as the fish would spoil

if they were not covered with pickle during the "striking" or salting process. The fish are thrown "face up" (cut surface, flesh side up) into the butts and sprinkled with salt as they are thrown in. Great stress is placed upon the even distribution of the salt. Between 6 and 7 bushels are used to each butt of fish. Turks Island salt is ordinarily used. Each butt yields approximately 500 pounds of dried cod. The rule holds: The warmer the weather the more salt used.

The fish are piled high above the top of the butt. The last few layers, those exposed, are piled with the backs up. A pile of salt is placed upon the top of the fish. By the day following the salting, the fish have settled below the top of the butt and the pile of salt has almost disappeared. Five or six more pecks of salt are then added to strengthen the pickle. Ordinarily the fish are allowed to remain in the butts from 10 days to 3 weeks. Only 3 days are required for the salt to penetrate through the fish, the remainder of the time being required for the fish to "strike through," or harden. After 3 days the flesh of the fish is still quite soft, but during the next 18 days it gradually becomes harder. If there is a large supply of fish on hand and if the demand is slack the fish are left in the butt much longer than 3 weeks. However, if allowed to remain there for too long a time the salted fish become yellow. This happens in the space of 2 months or less in hot weather, but in cold weather the fish may be left in the butts almost indefinitely. The amount of salt added (6 or 7 bushels) is far in excess of the amount actually taken up by the fish and dissolved in the pickle. This excess salt is used later in making more pickle.

After the fish are "struck" they are taken out of the butts, the slime is washed off, and the fish are piled in kenches about 4 feet high, face up, with the exception of the last few layers, which are piled face down in order to keep the top layers clean (free from dust). Weights are placed on top of the kenches to compress the fish and to squeeze out the pickle. Since the object of the kenching is to allow the fish to drain and partially dry, they are piled on racks about 8 inches above the floor. This enables the pickle to run out from under the piles of fish. The length of time during which the fish are left in the kenches depends mainly upon the weather and upon the amount of fish already upon the flakes. (See below.) During warm weather the fish are likely to spoil, so they are watched very closely and are repiled whenever there is danger of spoilage. The more often the fish are repiled the less time they must remain on the flakes; but the fish salters usually do not repile them more than once, since it requires a great deal of time. However, if the season is a rainy one, and they do not dry rapidly upon the flakes, the fish are rekenched several times.

After the fish are somewhat dry they are placed upon flakes for further drying. A flake is a rack (a lattice bed about 8 feet wide) built in the open, about 30 inches above a floor. The drying yard is known as the flake yard and is often located on a roof. The degree to which the fish are dried depends upon the trade. If the fish are to be sold in the southern States, they must be drier than if they are to be sold in the immediate vicinity. The length of time the fish must remain upon the flakes to dry to the required degree depends entirely upon the weather. The lower the humidity, the less time is

required for drying. The higher the velocity of the wind, the more rapidly the fish dry. When there is a driving wind two or three lots may be dried in a single day. When the weather is poor, however, it may take a week or more to dry a single lot. If the sun is hot, great care is taken to prevent the fish from becoming sunburned. Canvas is placed a few feet above the flake, and this prevents the direct-burning action of the sun. When the day is too hot, the fish are not placed upon the flake. If rain is imminent, they are collected and put under waterproof boxes on the flakes.

After drying, the fish are sorted as to quality and size. A first-quality fish should be uniformly white, have no bloodstains, possess a "sweet" smell, and be one of the thicker fish. After the fish are sorted they are hauled to the packing room. Before packing they are sprinkled with salt containing 0.4 per cent boracic acid, the amount of this mixture applied depending upon the climate of the region where the fish will be sold; the warmer the climate, the more of it used. This sprinkling of the dried fish with boracic-acid mixture is peculiar to this class of fish. No other salt fish is piled in kenches or dried on flakes. If the fish is for export, it is tied in bundles and packed in boxes or drums.

Although the method of cleaning, the cut appearance of the various fishes, and the amount of salt used all differ, mackerel, whiting, alewives, and herring are usually salted by the same general method in Gloucester. The exact procedure followed in salting one particular fish varies with the season and the trade, however.

The cleaned (cut) or round (uncut) fish are dipped in salt, the fineness of the salt and the quantity used depending upon the variety of the fish and the season of the year. The dipped fish are packed in layers in barrels or butts, salt is scattered over each layer, and, as in the case of cod, a small pile of salt is placed on top of the fish. The fish are then allowed to make their own pickle, and within 24 hours enough has been formed to cover them. The pile of salt on top of the fish is replenished on the second day.

Ample time is allowed for the fish to become thoroughly "struck," or salted, before they are touched again. This period is usually at least 30 days. The fish are then repacked tightly in barrels. In most cases a small amount of salt is placed over the top. The barrel is then headed and a bunghole bored in it, after which it is rolled on its side and filled with 100° brine (saturated salt solution).

REEDVILLE, VA.

Along the Chesapeake Bay, in the vicinity of Reedville, Va., there are about 40 fish-salting plants. Almost the only fish salted on a large scale is the alewife, or river herring. There is little organization among the fish salters of this region, due, in part, to the very short season. At Irvington the plants often operate no longer than six days. At Reedville the plants operate for about three weeks; however, the rush season lasts only a week.

The packers in this vicinity salt fish in a way distinctly different from that used in any other section of the country, with the exception of Havre de Grace, where for the most part, a similar method is used. The washed, cut river herring are dumped into large vats filled

one-sixth full with 100° pickle (saturated salt solution). As the fish are placed in the tanks salt is scattered over each layer. Each day the fish are roused (stirred up) with large paddles and more salt is added, usually in sufficient quantity to make the pickle saturated (100°); but the procedure varies in the different plants. Some fish salters (those in the vicinity of Irvington) keep their brine at 70 per cent saturation (70°). Even if the brine used at the start is saturated, by the following morning, when the fish are stirred for the first time, the pickle is not stronger than 60°. If a very large excess of salt is added when the fish are put in, this lowering of the concentration of the salt solution may be obviated to a considerable extent; but, as the fish are immersed loosely in a large excess of pickle, there is a tendency for the salt to sink to the bottom of the vat. As a result the pickle on top is always below saturation, whereas the bottom layers are saturated, or very nearly so.

At the end of from 7 to 10 days the fish are scooped out of the vats and hauled to a draining floor, where they are placed loosely in piles about 18 inches deep. They are allowed to drain and dry for three or four days. Then the salted river herring are packed tightly in layers in barrels, and a quart of Turks Island salt is scattered between each two layers of fish. No brine is added to these barrels, as the fish are sold dry. It is to be noted that in this region brine is added to the fish when they are salted, and after salting they are sold dry; whereas in Gloucester the alewives are salted with dry salt, without the addition of brine, and are sold in brine (pickle).

EDENTON, N. C.

Most of the fish salted in this region are river herring, or alewives. Most of the fishermen salt their own catches of fish. The fish-salting plants are, therefore, small, even smaller than those in the vicinity of Reedville. The season here is also short, usually lasting about six weeks.

In this region greater care is taken to wash the cut (cleaned) fish more perfectly. As a result, the salt river herring produced is of a little better quality than that produced elsewhere. The fish are mixed with salt with shovels and are shoveled into butts without any particular packing. They are allowed to remain in the butts from 8 to 12 days, after which they are piled on the floor to dry and drain for three or four days, in the same way that they are handled at Reedville. They are then packed tightly in barrels. About a quart of Turks Island salt is scattered over each layer of fish; no brine is added.

HAVRE DE GRACE, MD.

In Havre de Grace practically the identical procedure is followed in salting fish as in Reedville, Va. Aside from one plant, in which some fish are salted by a modified "Scotch" method, there are no important differences from the Reedville method. This modified "Scotch" method involves the salting of the round (uncut) alewives with dry salt. The fish are packed tightly in barrels, covered, and allowed to develop their own pickle. This method is similar to the one followed at Boothbay Harbor. However, at Boothbay Harbor

the fish are "gibbed" or "pipped." That is to say, the gills are cut out, and the viscera, with the exception of the roe or milt, are pulled out. The fish are sold in brine.

BOOTHBAY HARBOR, ME.

Herring is the principal fish packed in Boothbay Harbor. Most of the fish are Scotch-cured here. In this process the pipped fish are mixed with fine salt by hand without being washed. They are then carefully packed in barrels. Salt is sprinkled over each layer. A day or so later the barrels are filled up with herring of the same day's pack. After 9 or 10 days the barrel is drained of the old pickle, and the fish are washed with it without unpacking. The barrel is then completely filled with fish and filled through the bunghole with 100°, or full-strength, brine. The peculiarity of this method is that the fish are not washed before being salted. Therefore, every bit of blood in the cut fish either remains in the fish or goes into the pickle.

SUMMARY.

As stated previously, no effort has been made to include all the variations of the different methods of salting fish. Neither has any attempt been made to discuss any detail other than the mode of applying the salt to the fish. From the above description it is seen that all the methods include but three general modes of application of salt to fish: 1. The fish are immersed in a solution of salt which is kept saturated, or nearly so, by the addition of salt from day to day. 2. The fish are packed in water-tight containers with dry salt and are allowed to develop their own pickle. 3. The fish are packed in piles (kenches), and the pickle is permitted to run off the fish as it is formed.

The last-mentioned method is used only in cold weather, in an emergency when there are no containers at hand. Such is often the case on ships fortunate enough to make extraordinarily large catches. As it is practical only in cold weather, the method is not available for much commercial fish salting, and therefore no experimental work with it has been attempted.

The brine method of salting fish is chiefly used along the Chesapeake Bay, in the Reedville (Va.), and Havre de Grace (Md.) regions. This method has the big disadvantage of requiring more labor than the dry-salt method. Some salt must be added nearly every day, and the pickle must be watched closely to prevent it from becoming too weak. The fish must be roused (stirred up) every day. This is done with large paddles of various sizes and shapes and requires the expenditure of considerable energy. The fish produced by this method are much softer and contain more water than those produced by the dry-salt method. They appear similar to partially "struck," dry-salted fish. However, the fish are more plump and seem more like fresh fish than the dry-salted product.

The dry-salt method involves no rousing after salting and necessitates but one addition of salt, provided the fish are properly salted in the beginning. Usually the fish salted by this method are tightly packed in barrels or butts and not disturbed. This prevents the salt from falling to the bottom, as is the case when the brine-salted fish

are roused. Fewer scales are knocked off, and the fish have a wrinkled, shrunken appearance. If a lot of dry-salted fish is mixed with a lot of brine-salted fish, the fish can easily be separated, so marked is the difference in their appearance.

STORAGE OF SALTED FISH.

There are three general methods of storage: 1. the brine; 2. dry, with salt; 3, dry, with boracic acid. The quality of the fish on the retail market depends to a considerable extent upon the temperature and method of storage. No experimental work on storage was done.

The fish are kept in their own pickle or put in fresh saturated brine, or packed dry. If the pickle formed by the fish is dirty in appearance, it is discarded and fresh pickle (salt solution) is added. New brine is always added if the salt fish are likely to be stored in a place which is not cool. Fish dealers say that the "blood pickle" is likely to "sour" if kept in a warm place.

If the fish are packed dry, as are the cod in Massachusetts and the alewives in the South, they are packed either with salt or with boracic acid. The cod is sprinkled with salt containing 0.4 per cent boracic acid before packing. A considerable quantity of coarse salt is thrown over each layer of alewives as they are packed in the barrels.

In all cases the salted fish must be kept at a low temperature if they are to be stored for any length of time. The fish salted in Massachusetts and Maine are held in cold storage until the time of shipment. In North Carolina and Virginia the fish are held in "cool storage." Fish stored exposed to the air are very likely to "rust." Rusting is due to the oxidation of the fish oil and gives the fish a dark-brown color. Packing in brine prevents this to a large extent.

PURPOSE OF EXPERIMENTAL WORK.

This work was instituted in order to work out, if possible, a method of salting fish applicable in warm climates. At present none of the methods known are applicable for commercial purposes in a climate where the temperature averages above 70° F. Great care must be taken if the mean temperature rises above 60° F. The logical way to work out any new method is to study the existing methods first. This study should show whether some method in use to-day can be so improved that it may be used at a higher temperature. If, after the present procedures have been given a trial and their shortcomings discovered, no existing method can be adapted for warm climates, then the need for a new method will be shown.

FACTORS INFLUENCING THE SALTING OF FISH.

At the beginning it was evident that, if the various methods were to be fairly judged, the influence of the factors affecting the salting of fish would have to be known. Then, if all known methods were found incapable of being modified for use at higher temperatures, the relative values of the various factors would have been found, and improvements in the present methods might be suggested without further work. There would also be a basis of knowl-

edge with which a new method could be worked out. Besides, this plan of procedure would give data of great value. The application of correct interpretations of these data would lead to improved methods and a more uniform product. The relative importance of the factors influencing the salting of any fish being then known, the fish salter should be able to produce any desired product by modifying his conditions.

It has always been known that the relative freshness of a fish has an influence upon the quality of the salted fish. Everyone is aware of the fact that if fish are stale great care must be exercised in salting them in order to obtain a desirable product. There are no data in the literature which show how stale a fish may be and yet be salted satisfactorily. This result depends upon the efficiency of the method.

Any method that may be used to salt fish at high temperatures may also be used to salt stale fish. Since there is so little control of the present method of salting, little valuable data on this process could be obtained unless the available methods of salting fish were standardized so that uniform procedure would be followed in all cases.

Commercial fish salters are often very careless in allowing their fish to become stale before they salt them. The writer found it necessary to obtain the maximum temperature of salting perfectly fresh fish. Evidently the thoroughness of cleaning and washing the fish has an influence on the temperature at which they can be salted and also on the quality of the product. It is a well-known fact that unbled animals have a "wild-game" taste. The chief difference between the taste of domestic ducks and wild ducks is due to the fact that wild ducks are shot and not properly bled, whereas domesticated ducks are carefully bled. Fish salters are well aware of the fact that more care must be taken in the salting of round or uncut fish than in curing cut fish. Blood, milt, and roe are substances which decompose readily. Is it not possible that the presence of these substances in fish lower the maximum temperature at which they can be salted?

In the description of methods it was mentioned that there are three ways of applying salt to fish. The kench method of dry salting can be used in only cold weather. Prior to these experiments no one had shown which of the other two methods was the better during hot weather. In Massachusetts the dry-salt method is used the year around; yet in Virginia the fish salters are firm advocates of the brine method.

The resistance of the skin to the penetration of salt is another factor of importance in salting fish. Almost every fish salter will inform you that the salt penetrates more rapidly through the cut surface of the fish than through the skin. Would it not, then, be feasible to skin the fish before salting in warm weather?

Different modes of procedure are followed when various kinds of fish are salted. This in itself is evidence that the species of the fish is an important factor to be considered when working out any method of salting fish. The amount of fat in the different species of fish varies greatly—from about 0.09 per cent in cod to about 16.2 per cent in fat mackerel. The fat in a fatty fish might alter the

permeability of a fish to salt. The fat of different fishes varies widely in chemical composition and physical constants. Some fats may spoil more readily than others and thus affect the keeping qualities of the fish. Fish of different species vary in chemical composition. Everyone knows that some fish soften and spoil much more readily than others. Fish of the same and different species vary greatly in size. The surface exposed to the salt depends upon the size and shape.

MODE OF PROCEDURE IN EXPERIMENTAL WORK.

The chemical changes which fat undergoes during salting and storage were not studied, so that any points presented on this subject are merely casual observations which the experimenter noted during his work. The writer used but four species of fish in this work; naturally, therefore, it is not certain that the work applies to all varieties of fish. Most of the work was done with the squeteague (*Cynoscion regalis*) and the alewives (*Pomolobus æstivalis* and *pseudoharengus*). No marked differences were observed in the changes taking place during the salting of these fish. The writer ventures the opinion that the rules observed as to the protein decomposition (flesh decomposition) will apply to nearly every species of fish; but he doubts whether any observations concerning the chemical changes occurring in the fat of one species will hold good for all others, for the various fat constants of the oil of different species vary considerably. The rate of oxidation of these fats would vary nearly as much as the composition, because certain fish oils are much less saturated than others and would oxidize much more readily.

With the exception of the chemical changes taking place in the fat and the fact that the species studied were few in number, the writer believes that he has covered in this paper all of the most important factors influencing the salting of fish. The two factors not studied in detail embrace such a large amount of work that they were considered as separate problems.

Few important chemical investigations concerning the salting of fish have been carried out. Previously the problem had been considered mainly from the bacteriological standpoint. Various investigations concerning bacteriological problems had been attempted, but no methods of estimating the rate of salting, the rate of protein decomposition, or the freshness of fish were to be found in the literature. The investigator had, therefore, to work out and standardize methods applicable for his purpose. This in itself was no small task. The writer does not claim that the methods used are perfect or that other procedures could not be used to better advantage but rather admits that they may be improved upon. However, the procedure was uniform, and the results obtained checked satisfactorily in most cases. They must, therefore, be accepted as relative if not exact.

It seems obvious that the more rapidly salt penetrates the flesh of the fish the sooner decomposition of the tissue will stop. This statement is based on the assumption that decomposition of the tissue ceases when the fish is thoroughly salted. But this is not exactly the case. Decomposition is not stopped; it proceeds almost

infinitely more slowly. The decomposition products are also changed in nature, but no toxic compounds are developed. Later the salted fish may spoil because of unfavorable storage conditions, but it is not likely that the spoiled fish will produce harmful results if eaten. In order, therefore, to learn how fast salt penetrates a fish, a method was required which would enable the experimenter to determine the rate of penetration. This should enable him to judge, at least from one standpoint, the value of different salts.

The rate of penetration of salt into fish was followed by cutting sections of the fish at different depths from the surface. These sections were ashed and the amount of chlorine in them determined. The amount of chlorine in the dry salt fish was then calculated. This was done from day to day, and thus the increase in salt content of the inner sections was determined. The rate of penetration of any salt into fish is not an absolutely accurate criterion for judging the quality of that salt, for certain impurities in the salt might have a preservative action surpassing that of the salt.

Then it was necessary for the experimenter to learn the best method of cleaning fish preparatory for salting and to judge the necessity of absolute freshness. The rate of penetration does not afford a means of judging between two methods of application of the salt. It was necessary, therefore, to choose some means of estimating the decomposition of the flesh of fish and to adapt it for use with salt fish. A wide choice was not permissible, for a very large number of determinations must be run simultaneously and quickly. The apparatus required had to be simple and easily transported, as it was necessary to take the laboratory to the fish, as it were, in order to obtain fresh fish. The estimation of the rate of amino-acid formation was chosen as an indicator of the rate of protein decomposition. The reasons for this choice will be explained further on.

A limited amount of histological work was carried on in order to determine if possible the difference between the effect on the cell structure of the salted fish of pure sodium chloride and of sodium chloride adulterated with other chlorides. A complete record was kept of the macroscopic changes of each lot of fish. All the ordinary qualities were observed, such as color, odor, hardness, brittleness, taste, and general appearance. For the sake of brevity only the most notable changes are recorded in this paper. All edible samples of salted fish were cooked at the end of the experiments and their palatability noted. In these culinary experiments the fish were cooked in such a way that their flavor was in no way disguised.

The writer presents in this paper only those conclusions that seem to him to have been proved beyond doubt. The results may be accepted as facts for the river herring and the squeteague. It is very probable that they hold for other fish, but further work must be done to prove this point beyond doubt. In no case are the figures absolutely exact; but there is little doubt that they are relative to each other and that they may be compared with confidence. The writer hopes that this research will create such an interest in the chemistry of fish salting that other researches of a similar nature will be instituted.

EXPERIMENTAL.

I. INFLUENCE OF IMPURITIES IN SALT IN SALTING FISH.

INTRODUCTION.

Nearly every fish salter is a firm advocate of the use of some brand of commercial salt. A few fish salters realize that the foreign solar salts produce fish of a quality different from the domestic vacuum pan salts, but nearly all of these fishermen think that the difference in the product is caused by the variation in the size of the salt grains. Very few think that the impurities in the salt affect the hardness, whiteness, and other properties of the salted fish. Only a few salters understand the real meanings of the trade names by which the salt is sold. Many believe that "ground alum" refers to the quality of the salt sold under that name and would be surprised to learn that this name refers merely to the fineness of the salt.

Fishermen say: "That grade of salt rots fish." The action of the salt on fish is not clearly understood by all fish salters and salt dealers. This work on the influence of impurities is worth while, even if it merely explains the effects of the common impurities in salt. This will give the fish salter some criterion for judging the value of the various salts.

COMMERCIAL SOURCES OF SALT.

The greater proportion of the salt used in this country previous to the war was solar salt prepared in Europe or in the West Indies. Most of this European salt is made by evaporation of sea water along the coast or on islands in the Mediterranean Sea. The chief reason for the use of this salt is the cheapness of transportation facilities from those parts of the world to the Atlantic seaboard, where most of the European salt used in America is consumed. A great deal more material is exported from the United States to Mediterranean ports than is imported from these ports. Steamers are very anxious to bring cargoes from the Mediterranean Sea to the Atlantic ports, and therefore they are willing to transport the salt to our shores for a very small price.

However, during the war this supply was almost cut off. The price of salt in the United States rose to a very high figure, and the greater proportion of the salt used was domestic. Fish salters who had previously been prejudiced against the use of American salt were forced to use it, and many of them became convinced that it was equal in quality, if not superior, to foreign solar salts.

METHODS OF MANUFACTURE.

Domestic salt is prepared by one of the following processes: Steam evaporation, vacuum evaporation, direct-heat evaporation, or solar evaporation.

Most of the salt produced in the eastern part of America, close to the regions where fish are salted, is manufactured by steam evaporation. The product produced by this method, in jacketed kettles, grainers, and vacuum pans, is a fine-grained salt. For some reason there is much prejudice against the use of fine-grained salt for fish salting. Because of this prejudice very little salt produced in this way was used by fishermen previous to the war. During the war, when the supply of coarse-grained salt was limited, a large proportion of the fish salters began the use of fine-grained salt partially to replace the coarse-grained salts.

The salts produced by direct-heat evaporation are usually coarser grained than those produced by steam evaporation. To-day this process is seldom used except where it is possible to utilize waste heat, and since such a small amount is prepared in this way, this method of production is not considered an important factor in the salt supply.

Unfortunately for the fish trade, nearly all of the domestic solar salt is produced in the arid regions of the West. The only place in the East where this method of evaporation is practiced is in the vicinity of Syracuse, N. Y. Because of the very high freight rates eastward across the continent, the cost of the western solar salt on the Atlantic coast is almost prohibitive.

Pure salt is pure sodium chloride. There is no brand of commercial salt on the market that is 100 per cent pure. There are, however, salts on the market which are 99.95 per cent pure. Most of the American salts are of greater purity than the foreign salts; however, there are a few British salts of great purity. The limited analytical data available to the author indicate that British salts, with the exception of Turks Island are, on the whole, of much greater purity than French, Spanish, and Italian salts. The reason for this probably is to be found in the method of manufacture. The southern European salts are mainly solar salts, whereas the British salts, because of the climate, must be prepared in some other way.

The ordinary procedure in the preparation of solar salts is to allow sea water at high tide to run, or be pumped, into low-lying lands, forming ponds. The outlet to the sea is then closed, and evaporation is allowed to proceed. As the brine becomes more concentrated and more nearly saturated it is run into other ponds. Finally, when the saturation point has been reached the brine is run into crystallizing ponds. Here the usual procedure is to allow evaporation to proceed until the brine becomes high in magnesium chloride and low in sodium chloride. Usually when a concentration of 32° B. is reached the mother liquor is drained off and discarded. From the above brief description of the process it will be seen that solar salt is likely to be impure. Since sea water is high in calcium and magnesium chlorides, it is likely that solar salt will be high in these constituents if it is crystallized but once.

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ANALYSES OF COMMERCIAL SALTS.

The following are analyses of various typical commercial brands of salt:

ANALYSES OF VARIOUS SALTS USED FOR CURING FISH.[a]

Determinations.	Italian salt, Trapani.[b]	Spanish salt, Iviza.[b]	Domestic salt, Diamond Flake.[c]
	Per cent.	*Per cent.*	*Per cent.*
Sodium chloride	95.82	98.05	99.78
Calcium chloride	.32	.49	....
Calcium sulphate	....	....	.37
Magnesium chloride	1.19	....	.00
Magnesium sulphate	1.75	.80	.00
Sand	.15	.06	.00

[a] The sulphates were all calculated as magnesium sulphate and the calcium as chloride, except in the case of Diamond Flake salt, where no magnesium was found. In this case the sulphate was calculated as calcium sulphate.

[b] These results were calculated to a moisture-free basis from the data in the table, page 18, Bitting, A. W., Bureau of Chemistry Bulletin No. 133.

[c] Analyst, J. F. Stephl.

ANALYSES OF SAMPLES OF SALT.[a]

[Per cent on moisture-free basis.]

	Domestic salts.			Imported salts.					
				England.				Bahama Islands.	
	California: 23606–H, Leslie bulk salt from barrels, Leslie Salt Refining Co.[b]	New York: 11309–H, solar rock salt bulk, Solar Salt Co., Syracuse.[c]	West Virginia: MD–16102, Liverpool Salt Co., Hartford.[d]	P-8036, Ashton Higgin & Co., Liverpool.[e]	CN–2684, Chas. Moore & Co., Liverpool.[f]	France: P–7917, Bonaire Salt Exp. Co.[g]	Spain: P–8657, Pela Emprexado Navagacoa, Lisbon.[h]	P–7853, D. F. & H. F. Harriott, Turks Island.[i]	B–9015–16, Alfred Slotts Estate, Turks Island.[j]
RADICALS.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Arsenate (AsO_4)				Slight trace.	Trace.		None.	None.	
Tetraborate (B_4O_7)	None.			None.	Trace.	(?)	Trace.	None.	Trace.
Sulphate (SO_4)	0.021	1.365	0.00	0.89	Trace.	1.692	1.727	1.72	0.403
Carbonate (CO_3)					.000		.000		
Bicarbonate (HCO_3)					.031		.013		
Chloride (Cl)	60.70	59.51		59.81	60.63	58.51	59.34	59.44	60.16
Iron (Fe)			.007						
Calcium (Ca)	.025	.598	1.33	.39	.000	.764	.471	.45	.167
Strontium (Sr)			.81				.008		
Barium (Ba)			.67						
Magnesium (Mg)	.000	.000	.29	.02	Trace.	.090	.396	.47	.022
Sodium (Na, calculated)	39.34	38.56		38.73	39.34	37.71	38.02	37.97	38.98
Silica sand, etc. (SiO_2)	.008	.06		.02	.015	1.312	.086	.13	.293
Total	100.09	100.09		99.86	100.02	100.08	100.06	100.18	100.03

[a] Analyses supplied by and published by permission of the U. S. Bureau of Chemistry.
[b] Collected Sept. 5, 1914; analyst, W. F. Baughman.
[c] Collected Sept. 8, 1914; analyst, W. F. Baughman.
[d] Collected from Grainer May, 1913; analyst, W. F. Baughman. This salt is not supposed to be used for food purposes.
[e] Collected Feb. 4, 1916; analyst, C. H. Badger.
[f] Collected Oct. 6, 1914; analyst, R. H. Kellner.
[g] Collected Dec. 1, 1915; analyst, W. F. Baughman.
[h] Collected July 11, 1917; analysts, W. F. Baughman and R. H. Kellner.
[i] Collected Nov. 1, 1915; analyst, C. H. Badger.
[j] Collected Nov. 10, 1915; analyst, W. F. Baughman.

ANALYSES OF SAMPLES OF SALT—Continued.

	Domestic salts.			Imported salts.					
				England.				Bahama Islands.	
	California: 23606-H, Leslie bulk salt from barrels, Leslie Salt Refining Co.	New York: 11309-H, solar rock salt bulk, Solar Salt Co., Syracuse.	West Virginia: MD-16102, Liverpool Salt Co., Hartford.	P-8036, Ashton Higgin & Co., Liverpool.	CN-2684, Chas. Moore & Co., Liverpool.	France: P-7917, Bonaire Salt Exp. Co.	Spain: P-8657, Pela Emprexado Navagacoa, Lisbon.	P-7853, D. F. & H. F. Harriott, Turks Island.	B-9015-16, Alfred Slotts Estate, Turks Island.
COMBINATIONS.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sodium chloride ($NaCl$)	100.01	98.02	[a]92.70	98.45	99.96	95.86	96.63	96.52	99.09
Sodium bicarbonate ($NaHCO_3$)					.043		.018		
Magnesium chloride ($MgCl_2$)			1.13	.08		.35	.967	1.20	.08
Magnesium sulphate ($MgSO_4$)							.737	.80	
Calcium chloride ($CaCl_2$)	.045	.08	3.68	.05		.16			
Calcium sulphate ($CaSO_4$)	.030	1.93		1.26		2.40	1.602	1.53	.57
Strontium chloride ($SrCl_2$)			1.46						
Strontium sulphate ($SrSO_4$)							.017		
Barium chloride ($BaCl_2$)			1.02						
Ferric oxide (Fe_2O_3)			.01						
Silica sand, etc. (SiO_2)	.008	.06		.02	.015	1.312	.086	.13	.293
Total	100.09	100.09	100.00	99.86	100.02	100.08	100.06	100.18	100.03
Moisture	.159	1.12	5.66	.84	.139	1.39	4.475	4.19	.31
Remarks	Fine crystals.			Fine crystals.		Coarse crystals.	Coarse crystals.	Coarse crystals.	Large crystalline lumps.

a By difference.

These analyses are given in order to show the large amounts of impurities contained in some salts and to point out that it is possible to purchase on the market salts that are very nearly pure. It is to be noted that the chief impurities are calcium, magnesium, and sulphates. It is not known in just what chemical combination these occur in the salt, but this makes no difference. The analyses are given on a moisture-free basis in order that they shall be relative to each other. Further, the amount of moisture contained in salt is of little importance to the fish salter; except that, of course, damp salt contains less salt per ton than dry salt and, therefore, is more expensive if it is purchased at the same price.

INFLUENCE OF IMPURITIES ON RATE OF PENETRATION OF SALT.

INTRODUCTION.

Former work on rate of penetration.—Bitting (1911), of the Bureau of Chemistry, tried some experiments to show the effect of fineness of salt upon the rate of penetration of salt into codfish. Bitting's data show that in various coarse and fine salts there was little difference in the rate of extraction of water from the tissues or in the rate of penetration of salt into the fish. However, in his work no consideration was given the chemical composition of the salt. To make the work comparative, a single salt ground to different degrees of fineness would have to be used in salting all of the experimental lots of fish. Bitting used various domestic and foreign salts which were of different degrees of fineness, but which varied widely in chemical composition. It is stated that the cod used were small in size, but no information was given regarding the uniformity of size, which is a very important factor, as salt will penetrate to the center of a thick fish much less readily than it will penetrate a thinner fish. Nor does Bitting give any information as to his method of obtaining a 50-gram sample from a fish. Before the experiments could be repeated the exact size of the fish used would have to be known and also the exact method of sampling. The writer doubts that any method of sampling a fish other than sampling a section of given thickness a definite distance from the skin or flesh side of the fish would be accurate enough to show differences in the penetrating powers of different salts.

Importance of rate of penetration.—A consideration of the cause of souring had suggested that the souring is a decomposition of the inner meat of the fish before the brine strikes through and stops the decay. Various writers had observed an antagonism between the bivalent metals and monovalent metals in their passage through membrane. This suggested that the small amounts of calcium and magnesium, which exist in commercial salt as impurities, might exert a pronounced retardation on the penetration of the sodium chloride into the fish. An attempt was, therefore, made to measure the influence of these metals on the penetration of the sodium chloride into fish. If it were found that these impurities in salt caused the salt to penetrate more slowly, then the use of purer salt would lessen the danger of spoilage, for the fish would strike through more rapidly and less time would be allowed for decay of the inner portion.

An attempt was, therefore, made to measure the rate of penetration of pure salt into fish as compared with the rate of penetration of mixtures of sodium chloride with the common impurities in salt; that is calcium, magnesium, and sulphate.

METHOD.

It was fortunate that the writer began his experiments on the rate of penetration of salt with chemically pure sodium chloride, for this led to the discovery that the impurities in salt were largely responsible for the physical characteristics of the salted fish. The fish chosen for this work was the squeteague or weakfish (*Cynoscion regalis*), which could be obtained in a nearly fresh condition almost all the year around in Baltimore, where the experimenter was working. This fish is of medium fatness and was obtained on the market in quantity at any desired uniform size. It had been planned to try any improvement that might be worked out on the alewife or river herring. The squeteague was more similar to the river herring than any other fish that could be purchased throughout a long season.

After considering many possible methods of determining the rate of penetration of salt into fish it was decided to determine the per cent of chlorine in different sections of the fish from day to day. The layer from one half to 1 cm. in depth was found by experience to give the most uniform results.

Thus far the work has been applied to but one fish, the squeteague. The writer does not claim that the results of the work on this one fish can be applied without change to all varieties of fish. Different results might be obtained if a fat fish, such as the mackerel, had been used. Clark and Almy (1918) give the fat content of a composite sample of weakfish, on May 1, as 2.34 per cent (fresh basis); on September 25 a similar composite sample contained 0.52 per cent. However, they observed also that different squeteague in the same school and various schools differ greatly in their fat content.

Fish in good condition and of as nearly uniform size as possible were obtained from wholesale fish dealers of Baltimore. After cutting the length of the belly, eviscerating, and removing the heads, they were salted with dry salt of known composition. The salt used was Baker's analyzed, chemically pure sodium chloride, or mixtures of this with other salts of the same grain size. This salt was just a little smaller grained than ground alum, or packer's salt, which is so widely used in the fish-salting industry. The salts were thoroughly mixed, so that all portions were of uniform composition. The fish were rolled in salt, and salt was sprinkled over each layer of fish, as is the practice of the trade. For every three parts, by weight, one part of salt was added when first salted.

After the fish had been in salt 24 hours one part, by weight, of salt was added for every 15 parts of fish. Later, at the end of six days, 1 part, by weight, of salt was added for every 30 parts of fish. The fish were placed belly down in 2-gallon stone jars. The above procedure was carried out in order to duplicate, if possible, the method of salting fish in use at Gloucester.

In the different experiments the temperature of salting was kept as near 68° F. as possible by surrounding the jars with running

water near this temperature. The temperature did not vary more than 2.7° from the average. The fish were sampled at about 48-hour intervals. In sampling, a transverse section, about 3 inches in width, was cut from a fish. A layer, 0.5 cm. in depth, was cut from the outside of the fish, which had been exposed to the brine. A second layer, underlying first layer 0.5 cm. thick, was then cut for a second sample. These samples were then dried at 100° C. and ground up. The percentage of chlorine was then determined by first carefully ashing the fish in silica dishes and afterwards titrating the chlorides with tenth-normal silver nitrate, using potassium chromate as indicator. The inner section (one-half to 1 cm. in depth) was found to be of the most uniform composition. Analysis of different fish from a single lot showed that this layer did not vary more than 1 per cent in chlorine.

DISCUSSION.

The results of the work which has been completed are given in Tables 1 to 4 and are shown graphically in the curves, figures 1 to 4. The work shown in Tables 2, 3, and 4 was all done at the same time with fish of the same relative freshness, and the temperatures of the brines were kept uniform. The work reported in Table 1 was done at a different time with a different lot of fish of somewhat larger size and heavier scale. As a result, the data in Table 1 are not comparable with those given in the other tables.

The results of the analyses of the dry fish samples are shown in Tables 1, 2, 3, and 4. The figures in all cases refer to the per cent of chlorine in dry fish. In Table 1 the analyses of sections of fish salted with a salt so prepared as to contain 1 per cent of calcium chloride and analyses of sections of similar squeteague salted with pure salt at the same time under identical conditions are presented.

Table 1.—Retardation of Penetration of Salt into Fish Due to 1 Per Cent of Calcium Chloride Impurity, Expressed in Terms of Per Cent of Chlorine in Dry Sample, at 62.5° F.

Analysis of salt used.	Section of fish.	Per cent chlorine after—			
		1 day.	4 days.	7 days.	10 days.
Pure sodium chloride	Outer [a]	9.8	16.2	19.6	19.5
Do	Inner [b]	2.6	11.0	16.0	18.7
1 per cent calcium chloride, 99 per cent sodium chloride.	Outer [a]	8.7	10.8	15.2	16.6
Do	Inner [b]	2.5	7.9	14.1	14.4

[a] 0 to ½ cm. [b] ½ to 1 cm.

It is to be noted that the sections, both inner and outer, of the fish salted with pure salt ran higher in chlorine content than those salted with salt containing 1 per cent of calcium chloride.

In Table 2 data are presented which were obtained from the salting of another lot of squeteague with pure salt and from a similar lot salted with salt so prepared that it contained 1 per cent of magnesium chloride impurity.

TABLE 2.—RETARDATION OF PENETRATION OF SALT INTO FISH [a] DUE TO 1 PER CENT OF MAGNESIUM CHLORIDE IMPURITY, EXPRESSED IN PER CENT OF CHLORINE IN DRY SAMPLE, AT 68° F.

Analysis of salt used.	Per cent chlorine after—			
	1 day.	3 days.	6 days.	9 days.
Pure sodium chloride	9.8	16.0	19.7	22.4
1 per cent magnesium chloride, 99 per cent sodium chloride	6.5	15.7	18.7	19.0

[a] Inner section of fish, ½ to 1 cm.

In this case, also, the chlorine content of the inner sections of fish salted with pure salt is higher than that of similar sections of fish salted with the salt containing 1 per cent of magnesium chloride.

Table 3 shows that an increase in the amount of magnesium chloride to 4.7 per cent caused a further retardation.

TABLE 3.—RETARDATION OF PENETRATION OF SALT INTO FISH DUE TO 4.7 PER CENT OF MAGNESIUM CHLORIDE IMPURITY, EXPRESSED IN PER CENT OF CHLORINE IN DRY SAMPLE, AT 68° F.

Analysis of salt used.	Section of fish.	Per cent chlorine after—			
		1 day.	3 days.	6 days.	9 days.
Pure sodium chloride	Outer [a]	14.6	19.0	22.7	22.7
Do	Inner [b]	9.8	16.0	19.7	22.4
4.7 per cent magnesium chloride, 95.4 per cent sodium chloride.	Outer [a]	10.1	17.1	17.8	18.1
Do	Inner [b]	5.9	12.7	17.1	18.1

[a] 0 to ½ cm. [b] ½ to 1 cm.

Table 4 shows that the presence of the sulphate ion in solution caused a greater retardation than the consequent lowering of the concentration of the chlorine ion should cause.

TABLE 4.—RETARDATION OF PENETRATION OF SALT INTO FISH [a] DUE TO 10 PER CENT OF SODIUM SULPHATE IMPURITY, EXPRESSED IN PER CENT OF CHLORINE IN DRY SAMPLE, AT 68° F.

Analysis of salt used.	Per cent chlorine after—			
	1 day.	3 days.	6 days.	9 days.
Pure sodium chloride	9.8	16.0	19.7	22.4
10 per cent sodium sulphate, 90 per cent sodium chloride	7.1	10.5	15.3	17.1

[a] Inner section of fish, ½ to 1 cm.

Further than a retardation of the rate of penetration of the sodium chloride, calcium chloride and magnesium chloride had noticeable effects on the physical appearance of the salted fish. Both the calcium chloride and magnesium chloride as impurities in salt made a much harder fish than pure sodium chloride. Calcium chloride, apparently, was most active in this regard. Pure sodium chloride, when used dry for salting fish, produces a soft, yellow-meated fish which will bend when held in the hand. Five per cent of calcium

chloride as impurity is sufficient to produce a very stiff, hard fish. One per cent of calcium chloride produced a softer fish, but yet one which was much harder than that produced by pure sodium chloride. Four and seven-tenths per cent of magnesium chloride, as impurity, produced a fairly hard, stiff fish, with a very bright, shiny appearance.

Both calcium chloride and magnesium chloride, as impurities in salt, caused a very noticeable whitening. This whitening could easily

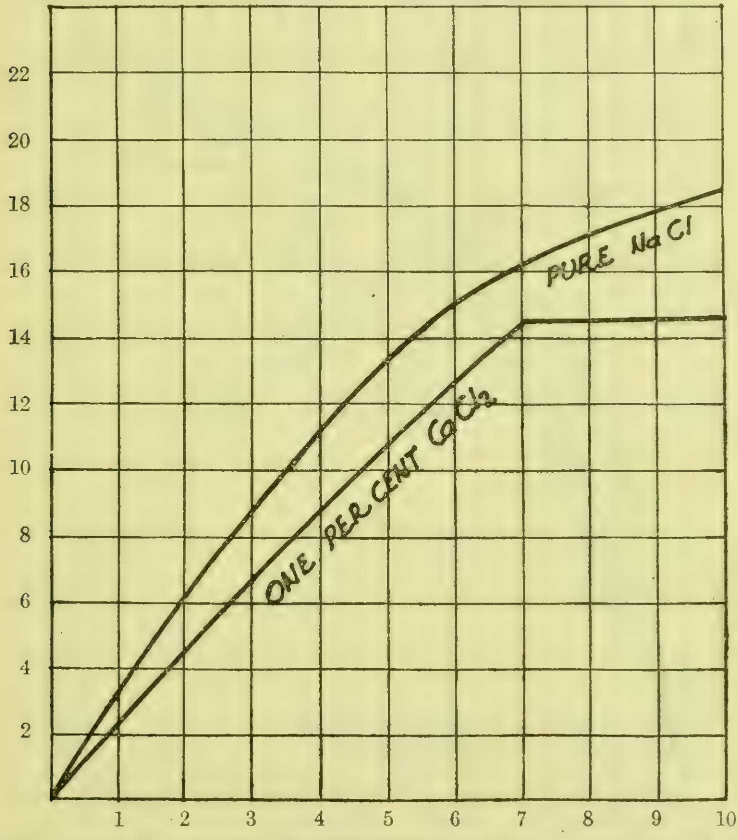

FIG. 1.—Curves show retardation of penetration of salt due to 1 per cent of calcium chloride impurity (section ½ to 1 cm. depth). Figures at left indicate per cent of chlorine in dry fish; at bottom, time in days.

be followed, as it was first observed in the outer portions of the fish and moved toward the center until at the end of from 10 to 13 days the fish was uniformly white throughout. Calcium chloride was most active in this regard.

Figures 1 to 4 illustrate graphically the data presented in the tables. In each case the time in days is plotted along the ordinate (horizontal line). The percentage of chlorine in the dry fish is plotted along the abscissa (vertical line).

Figure 1 shows how the percentage of chlorine in fish (the amount of sodium chloride contained in the fish) increases for 10 days. The

salts used were pure sodium chloride in one case and sodium chloride containing 1 per cent of calcium chloride in the other. It will be noted that after seven days the chlorine content of the fish salted with pure salt is nearly 2 per cent higher than that of the fish salted with salt containing 1 per cent of calcium chloride. The chlorine content of the fish salted with pure sodium chloride continues to increase rapidly, whereas the chlorine content of the squeteague salted

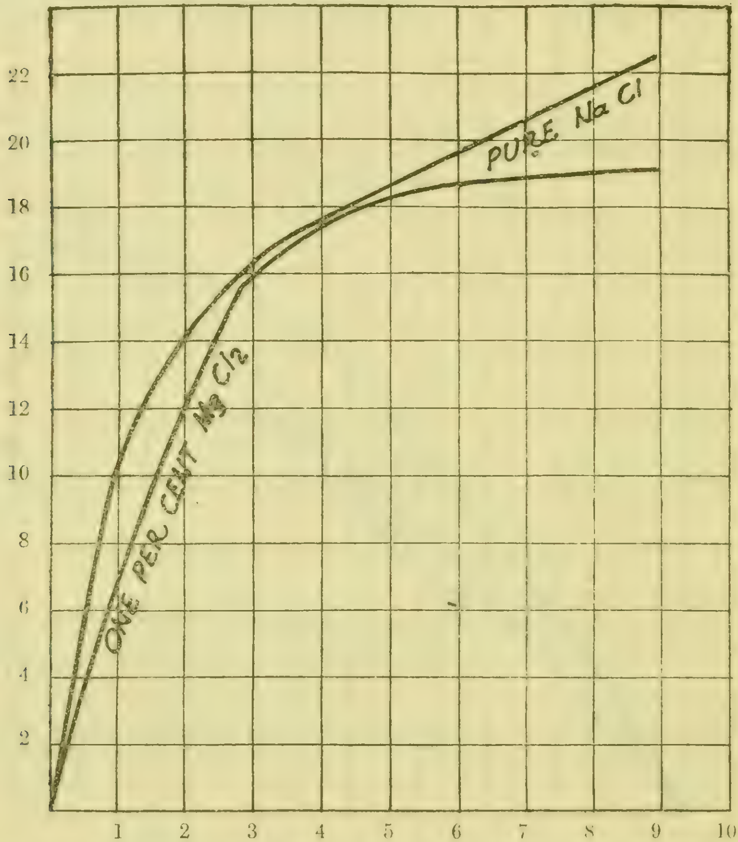

FIG. 2.—Curves show retardation of penetration of salt due to 1 per cent of magnesium chloride impurity (section ½ to 1 cm. depth). Figures at left indicate per cent of chlorine in dry fish; at bottom, time in days.

with salt containing calcium chloride increases very much more slowly.

Figures 2 and 3 show that the marked slowing up in the penetration of the salt into fish, due to the presence of magnesium chloride, begins in about six days after salting.

Figure 4 shows that the marked slowing up of the penetration of the salt into fish in the case of salt adulterated with 10 per cent of sodium sulphate occurs almost immediately. The amount of impurity used in this case was far in excess of any amount ever found in any commercial salt. It is doubtful whether small amounts of

sulphates found in commercial salts would have any appreciable effect on the penetration of salt in fish.

SUMMARY.

1. Small amounts of calcium chloride or magnesium chloride, as impurities in salt, retard the penetration of the sodium chloride into the squeteague.

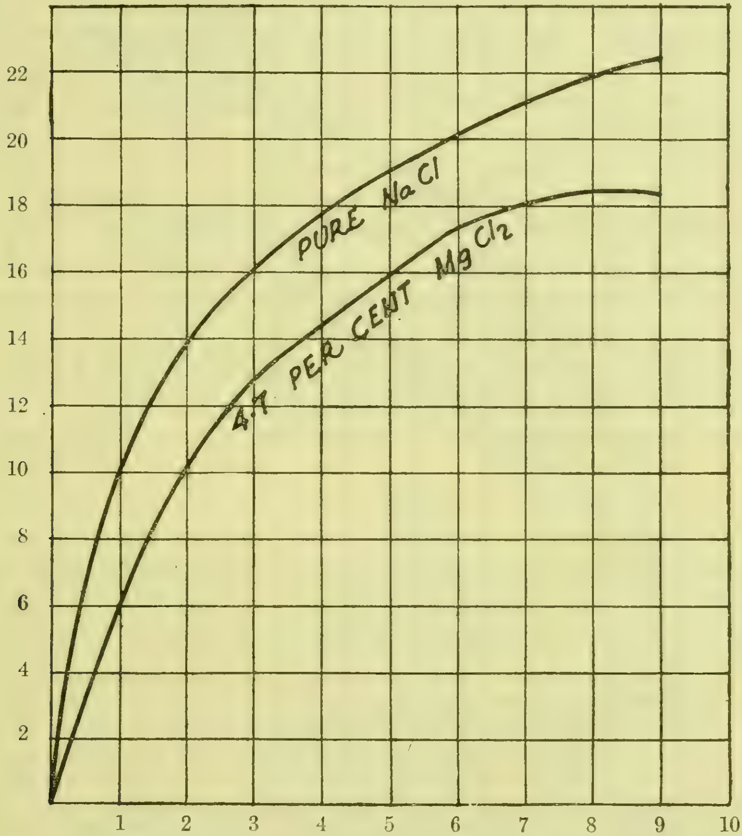

FIG. 3.—Curves show retardation of penetration of salt due to 4.7 per cent of magnesium chloride impurity (section one-half to 1 cm. depth). Figures at left indicate per cent of chlorine in dry fish; at bottom, time in days.

2. The sulphate ion has a similar, though less noticeable, effect.

3. Calcium chloride and magnesium chloride, as impurities in salt, cause a firmer, whiter fish than pure sodium chloride.

INFLUENCE OF IMPURITIES ON RATE OF PROTEIN DECOMPOSITION.[a]

INTRODUCTION.

When the consideration of obtaining the relative values of different methods of salting fish was first taken up, the rate of penetration of

[a] The analytical work reported in this section of the paper was done by J. F. Stephl, temporary assistant, U. S. Bureau of Fisheries.

chlorine into the fish was chosen as a criterion. The writer realized, however, that this alone was hardly a satisfactory criterion. Even if the salt penetrates fish with equal rapidity, it is no proof that the fish are keeping equally well. Different moisture contents would cause unequal keeping qualities; also, some impurities in the salt might have a greater preservative action than sodium chloride.

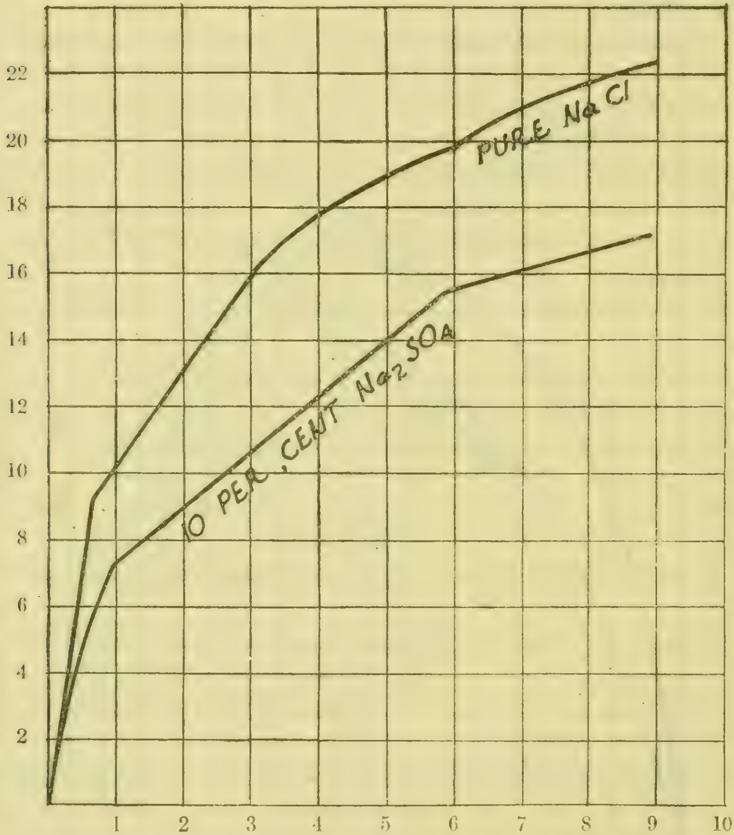

FIG. 4.—Curves show retardation of penetration of salt due to 10 per cent of sodium sulphate impurity (section one-half to 1 cm. depth). Figures at left indicate per cent of chlorine in dry fish; at bottom, time in days.

It was considered essential to have some means of measuring the amount and rate of decomposition of protein in order to judge as to how much decomposition took place while any given lot of fish was being salted. If the amount of decomposition at the end of the salting process were known, the real value of any salting method as a means of preserving fish would be known.

When proteins decompose, they break up, first, into simpler proteins, then into polypeptids, and then into amino acids. It is very difficult to measure accurately the amounts of simpler proteins and polypeptids in fish. However, the total amino-acid content of fish and brine is easily determined.

A number of experimenters have found that the amount of amino acid formed is an index of the total protein decomposition in meat and fish. Hoagland, McBryde, and Powick (1917), working on the decomposition of beef during cold storage, found that the amino-acid content of beef increased relatively more than any other constituent. They found that the amount of amino acid formed varied directly with the length of the storage period. They say:

> The increases in amino nitrogen represent an accumulation of the end products of proteolysis and furnish an excellent index of the extent of protein autolysis. They are produced by the combined action of various proteolytic enzymes—protease and erepsin in particular—upon muscle proteins and their cleavage products. * * *
>
> Amino nitrogen showed greater actual and relative changes than any other nitrogenous constituent. This result was to have been expected, since this constituent represents, in a large degree, an accumulation of the end products of proteolysis.

Bradley and Taylor (1917) used the estimation of amino acids by the formol-titration method to measure the rate of digestion of proteins.

Ottolenghi (1913) found that the amino-acid nitrogen content of meat was the best index of decomposition of meats. He used the amino-acid content to trace the ripening of meat to ascertain when active decomposition sets in. He found that only Sörensen's formol-titration method for determining amino-acid nitrogen and the microscopic examination for bacteria were of practical use for his purpose. Other methods were found to require too much time and elaborate manipulation.

METHODS.

Determination of amino-acid nitrogen.—It was necessary to use a method of estimating amino-acid nitrogen which did not require a complicated apparatus. The procedure had to be short, so that a large number of analyses could be made in a day. The formol-titration method is the only one that fulfills these requirements. Therefore, the amino-acid nitrogen was estimated in all cases by Sörensen's formol-titration method as modified by Benedict and Murlin.

The writer is well aware that this method is open to many objections. There are many slight errors due to the loss of diamino acids by precipitation, the high results given by some amino acids, and the low results given by others, etc. But for use as a measure of decomposition of protein a method does not need necessarily to give the exact amount of amino-acid nitrogen present in the fish or brine. If it gives results which are relative in all cases, it is sufficiently accurate for use where the results are used as an index of decomposition.

The procedure in the determination of amino-acid nitrogen in pickle was as follows: Twenty-five c. c. of brine were measured into a beaker. A quantity of 10 per cent phosphotungstic acid in 2 per cent hydrochloric acid, sufficient to precipitate all the protein, was added. This was allowed to stand overnight. The solution was then filtered and the precipitate washed. One c. c. of a 0.5 per cent solution of phenolphthalein was added and barium hydrate in substance until the solution turned a permanent red. After standing at least half an hour the solution was filtered and the precipitate washed. The solution was then neutralized with half-normal hydrochloric

acid. Enough tenth-normal sodium hydroxide was then added to turn the solution very slightly pink. Then 10 c. c. of neutral 40 per cent formalin were added and the solution titrated with tenth-normal sodium hydroxide. A blank on the formalin was run and this subtracted or added, as the case might be.

When the determination was made on the fish, the procedure was varied as follows: Sections were cut from four fish. These were cut into small pieces and mixed. Twenty-five grams of this mixture were weighed out and then ground in a mortar for 5 minutes. Twenty-five grams of salt were added, and the sample was washed out of the mortar. The sample was then made up to 250 c. c. volume and was allowed to stand on ice overnight; then sufficient was filtered off through a dry filter to obtain a 50 c. c. sample which was treated as in the case of the brine.

Before sampling the salt the residual salt was thoroughly mixed after draining off the brine. A 25-gram sample was then weighed out. After dissolving the salt in water sufficient phosphotungstic acid was added to precipitate the protein and ammonia present. From this point the procedure was the same as for the brine and fish. In every case, after precipitation with phosphotungstic acid, the supernatant liquid was tested to see if enough phosphotungstic acid had been added.

Salting of fish.—Great emphasis was placed on uniformity of procedure throughout this experimental work. The experiments concerning protein decomposition as affected by the impurities in salt were carried out on river herring caught in the Albemarle Sound. These fish were purchased from fishermen and were iced as soon as they were brought ashore. This was about 1½ hours after capture. They were then immediately cleaned thoroughly. The following procedure was followed in salting lots numbered FA–1, FA–4, FA–5, and FA–6. These results are reported in Table 5, page 32.

The heads and all viscera were removed and the fish split along the belly to the vent. They were then soaked in ice water for an hour. The under side of the backbone was scraped free from blood, and all blood was washed out. The fish were then drained free from water, weighed, and salted. The river herring were rolled in salt and packed tightly, belly up, in layers in kits. Some salt was sprinkled over each layer of fish. No brine was added; the fish developed their own pickle. When packed, a weight of salt equal to one-third the weight of the fish was added. The following day a weight of salt equal to one-twelfth the weight of the fish was added.

The salt used was either the commercial brand of salt known as Diamond Flake, or mixtures of this salt with chemically pure salts of similar degrees of fineness. Diamond Flake salt is a fine-grained salt prepared in Michigan, the analysis of which is given on page 18.

Previously, an experiment had been run to determine whether the impurities present in commercial Diamond Flake salt were of sufficient importance to cause a variation in its preservative action on fish from that of chemically pure sodium chloride taken as a standard. The result of this work showed that the differences in the amounts of amino-acid nitrogen formed in these two cases was within the limit of the experimental error.

The kits of salted fish were immediately placed in a large, constant-temperature vat capable of holding seven small kits. The kits were held at a definite constant temperature throughout the salting period. In this case the temperature of lots FA–1, FA–4, FA–5, and FA–6 was held at 79° F.

These large, constant-temperature vats were steel tanks. They were about half filled with water, which was electrically heated. A framework was built around them, and the space between the framework and the vats was filled with sawdust. They were fitted with wood covers and were also covered with paper and oilcloth. This effectually thermally insulated them. Hasselbring thermoregulators operated a relay system which regulated the operation of the heaters. A water motor drove the stirrers, which efficiently kept the vats at a uniform temperature throughout. In this experiment the temperature did not vary more than 1° F. from the average.

Analysis of fish.—Samples of the fresh fish were analyzed at the beginning of the experiment. It was found that uniformly cleaned, fresh alewives have practically the same amino-acid content. In the case of the well-cleaned and well-washed alewives this is about 0.02 per cent amino-acid nitrogen (fresh basis). This fact might be utilized in judging freshness of fish.

At the end of the experiment the fish, brine, and salt were weighed and sampled. The samples were analyzed for amino-acid nitrogen, according to the method described. The total weights of amino-acid nitrogen in the brine, residual salt, and fish were calculated. These were added together, and the total weight of amino-acid nitrogen contained in the fresh fish subtracted from their sum. This gave the total weight of amino-acid nitrogen formed. This figure was divided by the original weight of the fish in kilograms. The result is the weight of the amino-acid nitrogen formed per kilogram of fish.

This work is based on the supposition that the greater the decomposition of protein the greater will be the amount of amino-acid nitrogen formed, inasmuch as the chief product of autolysis is amino-acid nitrogen. Where decomposition takes place so rapidly that the chief action is bacterial, amino-acid nitrogen is also formed; but in this case it is merely an intermediate product as the end products of bacterial action are ammonia and nitrogen. In such cases ammoniacal nitrogen ought also to be determined. The experimenter was always limited by lack of time and facilities for elaborate chemical work. This is inevitable unless the investigator has the use of a complete chemical laboratory close to a large continuous supply of fresh fish and has the help of a corps of assistants.

As long as there was but little spoilage of fish in the experiment, the results of the amino-acid determinations from different lots salted under identical conditions checked excellently. But when the spoilage was great enough to cause the formation of foul-smelling gases and was quite evidently of a bacterial nature the amounts of amino-acid formed did not show what was anticipated. Surely, in such cases the ammoniacal nitrogen ought to have been determined.

The results of the analyses and calculations are given in Table 5.

TABLE 5.—EFFECT OF CALCIUM CHLORIDE AND MAGNESIUM CHLORIDE IN SALT ON RATE OF AMINO-ACID FORMATION IN SALTED FISH.[a]

[Lots D refer to samples dry-salted, and lots S to those brine-salted.]

Lot No.	Method of cleaning.	Analysis of salt.	Weight of salt and brine used.	Salting period.		Weight of fresh fish.	Amino-acid nitrogen in fresh fish.	
				Average temperature.	Length.			
		Per cent.	*Kgs.*	*°F.*	*Days.*	*Grams.*	*Per ct.*	*Grams.*
FA-1:D	Heads removed; eviscerated; well washed.	5.0 calcium chloride; 0.37 calcium sulphate; 94.78 sodium chloride.	[c]1.66	79	7	4,000	0.02	0.80
FA-4:D	......do	5.0 magnesium chloride; 0.37 calcium sulphate; 94.78 sodium chloride...	[c]1.25	79	7	3,000	.02	.60
FA-5:D	......do	99.78 sodium chloride, Diamond Flake.	[c]1.25	79	7	3,000	.02	.60
FA-6:D	......do	......do	[c]1.25	79	7	3,000	.02	.60
DA-8:S	Heads removed; eviscerated with exception of milt and roe.	......do	[b]6, [c]1	75	9	5,000	.022	1.10
DA-9:S	......do	94.78 sodium chloride; 5.0 sodium sulphate; 0.37 calcium sulphate.	[b]6, [c]1	75	9	5,000	.022	1.10

Lot No.	Total amino-acid nitrogen at end in—				Amino-acid nitrogen formed.		Physical condition of salted fish.
	Fish.	Brine.	Salt.	Fish, brine, and salt.	Total.	Per kilogram fresh fish.	
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	
FA-1:D	2.20	0.53	0.07	2.80	2.00	0.500	Good; hard; whitened.
FA-4:D	1.17	.52	.05	1.74	1.14	.380	Do.
FA-5:D	1.00	.50	.07	1.57	.97	.323	Good; hard; yellow-white.
FA-6:D	1.07	.48	.06	1.61	1.01	.336	Do.
DA-8:S	2.46	2.09	None.	4.55	3.45	.69	Contained 2 bad fish; total number, 25.
DA-9:S	2.82	1.97	None.	4.79	3.69	.74	Contained 3 bad fish; total number, 25.

[a] The fish in this experiment were salted four hours after capture. [b] Brine. [c] Salt.

DISCUSSION.

Effect of calcium and magnesium salts.—It should be noted that the amounts of impurities, calcium, magnesium, and sodium sulphate that were added are great. The combined amounts of calcium and magnesium salts occurring in commercial salts is seldom over 4 per cent. The analyses given on pages 18 and 19 show the composition of various commercial salts.

More amino-acid nitrogen was formed in lot FA-1 than in lots FA-4, FA-5, or FA-6. Lots DA-8 and DA-9 were cleaned in a different manner and were salted in brine instead of dry salt; so these results are not comparable with the results of the lots numbered FA.

Lot FA–1 was salted with salt containing calcium chloride as impurity. This increase in the amount of amino-acid nitrogen formed was about 50 per cent over the weight of amino-acid nitrogen formed when pure salt was used. In other words, there was a half more decomposition of the protein when the salt contained 5 per cent of the calcium chloride than when no calcium chloride was present. Five per cent of calcium chloride is only the equivalent of 1.8 per cent of calcium. This is a greater amount than was contained in any whose analyses are given in the tables of salt analyses.

Salt sample number MD 16102 contained 1.33 per cent calcium. However, it will be noted that the total impurity amounted to 7.3 per cent. Lot FA–4 was salted with salt containing 5 per cent of magnesium chloride. In this case 0.380 gram of amino-acid nitrogen was formed during the salting period. This is 15 per cent more than when pure salt was used (FA–5, FA–6). However, 5 per cent of magnesium chloride is 1.28 per cent of magnesium, which is double the amount of magnesium likely to be found in any commercial salt.

If the salt analyses given previously are consulted, it will be seen that the Trapani salt sample is the only one that contains a very large amount of magnesium and that this amount is less than 3 per cent of total magnesium salts. It seems unlikely, therefore, that the amounts of magnesium salts contained in commercial salts have any appreciable deleterious effect on the fish-curing properties of any salt.

Effect of sodium sulphate.—Samples DA–8 and DA–9 were prepared for salting by cutting off the heads and cutting the length of the abdominal cavity. All viscera were removed with the exception of the milt or roe. As the milt and roe were left in the fish, it was impossible to wash the fish thoroughly, or to remove all the blood. For this reason the maximum temperature of salting was greatly lowered, even though all other conditions were identical. These fish were salted in brine. For every gram of fish taken 1 c. c. of brine was used. At the time of salting a considerable excess of solid salt was added. From time to time more solid salt was added. The fish were stirred daily. Sufficient salt was added to keep the pickle saturated at all times. The amount of salt required for this purpose was about one-fifth of a gram of salt for every gram of fish.

The samples were taken at the end of the salting period. They were analyzed, and the calculations were made in the manner previously described. Lot DA–8 was salted with nearly pure salt. The salt used in lot DA–9 contained 5 per cent sodium sulphate as impurity. These lots were salted just above the maximum temperature for fish cleaned in this way (containing roe, milt, and blood). Any differences in the preserving or penetrating powers of the salts used should show up very noticeably under these conditions. Yet there is only a difference of 7 per cent in the amount of amino-acid nitrogen formed. There is a little more decomposition in the case of the salt containing the sodium sulphate, but the difference is slight. There is usually not more than 2 per cent of sulphates contained in commercial salts. Had the amount of sodium sulphate been reduced to 2 per cent it is likely that the difference between the preservative power of the impure salt and the pure salt would have hardly been noticeable.

These results concerning the rate of formation of amino-acid nitrogen check with those on the penetration of chlorides; that is, where there was a slowing up in the rate of penetration of chlorides, there is an increase in the rate of amino-acid formation. The changes are approximately the same, except in the case of the effect of the sulphates. The results obtained from the work on rate of penetration of salt adulterated with sodium sulphate show a marked decrease in the rate of penetration, due to the impurity. The increase in rate of production of amino acids due to the presence of this impurity is very slight. However, the work on the rate of penetration was done with salts containing 10 per cent of sodium sulphate. It may be that this marked retardation takes place only at high concentrations of sodium sulphate, when there is a marked hardening of the tissues.

DISCUSSION.

PHYSICAL EFFECTS ON FISH.

This work on the preservative action of different salts was done on alewives, whereas the penetration of salts were followed in squeteagues. The hardening and whitening action of calcium and magnesium salts was marked on alewives; but it was less noticeable than in the case of squeteagues. Five per cent of sodium sulphate had practically no whitening action on alewives and very little hardening action. It may be that 10 per cent of sodium sulphate in salt is required to bring out the whitening power. No lot of alewives was salted with salt containing more than 5 per cent of sodium sulphate.

A POSSIBLE EXPLANATION OF RESULTS.

The writer believes that the hardening action of calcium and magnesium salts on the tissues of the fish is responsible for the retardation of the penetration of the chlorides. This, in turn, is at least partially responsible for the lesser preservative action of the impure salts. Sodium sulphate evidently acts only when in greater concentrations than it is ordinarily found in commercial salts. Its deleterious action as an impurity is, therefore, not to be feared.

PRACTICAL APPLICATION.

When fish are salted at any temperature averaging below 50° F., salts may be chosen that will produce the desired quality of salted fish. When a hard, white fish is desired, salts high in calcium and magnesium salts may wisely be chosen. However, if a soft, pliable fish is desired, pure salts should be used.

When the average temperature of salting is above 50° F., greater care should be used in the selection of salt. This becomes of particular importance when the fish are salted, either round or containing blood, roe, or milt, as these fish are much more likely to spoil than when they are thoroughly cleaned. In this case the smaller the amounts of calcium and magnesium salts present the more desirable the salt. Fish salters working in warm climates should strive to obtain salt containing less than 1 per cent of total calcium and magnesium salts. Sulphates are never present in large enough quantities to lower the effectiveness of the salt as a preservative.

EFFECT OF FINENESS OF SALT.

The writer considered the fineness of salt as of little importance, save in a physical way. Inasmuch as his time was limited, he conducted no experiments to determine the optimum degree of fineness of salt for use in fish salting. This factor is entirely eliminated when fish are salted by the brine method. When small fish are salted with dry salt, care must be taken not to use too coarse a salt, such as Turks Island. When such a coarse salt is used, great difficulty will be encountered in obtaining a uniform distribution of the salt throughout the barrel or butt of fish. Nearly all of the salt used will be on the outside of the fish. If, however, fine salt be used, a considerable portion of the salt will be inside the abdominal cavity. This abdominal cavity usually is quite moist; so almost immediately a strong pickle will be formed which will begin to penetrate the fish. Fine salt certainly has the advantage of being easier to distribute evenly throughout a container of fish regardless of the size of the fish. However, in the case of cod and other large fish fine salt gives the fish a somewhat different appearance. In such cases, when the weather is cold, appearance should be the first consideration. If such large fish are salted in warm, southern climates, less consideration can be given to the appearance of the product. In such climates the first considerations must be the composition of the salt and its uniform distribution throughout the container of fish.

SUMMARY.

Calcium and magnesium salts and various sulphates cause a retardation of the penetration of salt into fish. These salts also cause a less perfect preservation of the fish during salting. This was shown by increased amounts of amino acids formed during the salting period. Calcium is most powerful in this regard. Magnesium salts cause a considerable increase in the rate of decomposition during salting, other conditions being the same. But this effect is not nearly so great as that caused by calcium salts. Sulphates do not cause an appreciable increase in the rate of decomposition at the concentrations at which they are present in salt. The fish salter working under adverse conditions in warm climates should use care in the selection of his salts and choose salts that are low in calcium and magnesium.

II. A COMPARISON OF EFFICIENCY OF BRINE AND DRY SALT FOR SALTING FISH.

INTRODUCTION.

At present fish are salted either by the use of dry salt or brine and salt. Before improvements in either method could be suggested it was considered essential to know the relative merits of the two methods at various temperatures. The work presented in this section of this paper was undertaken, therefore, with that aim in view.

The dry-salt method involves the packing of fish with salt in a water-tight container. The water and body juices of the fish dissolves sufficient salt to make enough "pickle" to cover the fish. A small pile of salt is usually placed on top of the container to press

down the fish and keep them covered. The fish are not disturbed until the end of the salting period.

In the brine method of salting fish the procedure is as follows: Fish are dumped into a vat containing enough brine nearly to cover them, and a considerable quantity of salt is added along with the fish. Each day more salt is added, and the fish are stirred in the "pickle." The purpose of adding the salt is to maintain the brine as near saturation as possible.

In these experiments these two methods were given a trial. The commercial methods were imitated as closely as possible in order to fairly compare the methods.

DETERMINATION OF RATES OF PROTEIN DECOMPOSITION.

METHOD.

Ninety pounds of reasonably fresh squeteague (*Cynoscion regalis*) were obtained. The fish had been caught two days previously and had been kept on ice. There were 120 fish in all, making the average weight three-fourths of a pound. They were cut down the belly and eviscerated. The tails and heads were cut off, and the fish were washed in ice water.

After cleaning there remained 23.4 kg. of fish. These were divided into 12 lots. Six lots of 1.3 kg. each and six other lots containing 2.6 kg. each were weighed out. To each of the smaller lots were added 1,300 c. c. of saturated sodium chloride solution and 250 grams of pure, dry sodium chloride. The fish of the larger lots were rubbed in chemically pure dry salt and then packed in glass dishes, cut surface down, and sodium chloride was sprinkled over each layer. The 2.6 keg of fish just made two layers; 990 grams of salt were used in this way on each lot. The salt used in this experiment was chemically pure "Baker's analyzed" sodium chloride. This salt is a little smaller grained than "ground alum."

One of each of the lots of fish was then placed in a different constant-temperature compartment. The fish were permitted to remain in this constant-temperature apparatus for nine days. The brine-salted lots of fish were stirred daily. The temperature in any one compartment did not vary more than 1° F. from the average. The brines were sampled and analyzed for amino-acid nitrogen on the first, third, fifth, seventh, and ninth days. At the end of the experiment the fish and salt were also analyzed for amino-acid nitrogen. In the case of fish to which the brine had been added not more than 25 grams of salt remained undissolved. The amount of amino-acid nitrogen in this small amount of salt was considered negligible. In all cases, however, there was an excess of undissolved salt at the end of the salting period.

The method of sampling the fish, brine, and salt was described in the first section of this paper. The method of analysis of the samples for amino-acid nitrogen was the formol-titration method, which was described on page 29.

DISCUSSION.

Table 6 shows the titration values obtained by the formol titration for amino acids of 25 c. c. of the brines. These figures are given

to show the rate at which the amino acid diffuses out into the brine. They also point out a means of forecasting spoilage of fish.

TABLE 6.—INCREASE IN AMINO-ACID CONTENT OF BRINES.

[Figures refer to c. c. N/10 NaOH amino acid contained in 25 c. c. of brine: Lots D refer to samples dry salted; lots S, to those brine salted.]

Lot.	Brine collected after—					Temperature.
	19 hours.	67 hours.	5 days.	7 days.	9 days.	
	C. c.	*C. c.*	*C. c.*	*C. c.*	*C. c.*	*° F.*
2 D	4.7	5.0	5.1	5.1	6.5	63
2 S	1.3	2.0	2.1	2.7	3.4	63
3 D	4.7	4.9	5.6	5.4	7.1	70
3 S	1.4	2.4	2.3	2.7	4.2	70
4 D	4.4	5.2	5.7	5.9	7.6	75.5
4 S	1.4	2.6	2.5	3.2	4.4	75.5
5 D	4.4	5.1	7.0	7.6	8.5	80
5 S	1.2	2.7	3.0	4.2	[a] 5.3	80
6 D	4.1	4.8	8.7	[a] 9.6	[a] 10.1	87
6 S	1.3	3.4	3.7	[a] 5.2	[a] 7.2	87
7 D	4.4	7.2	[a] 10.3	[a] 13.0	[a] 16.0	93
7 S	1.1	3.4	[a] 4.6	[a] 6.6	[a] 9.5	93

[a] Spoilage of fish noted.

Apparently the water contained in the fish diffuses out more rapidly in the case of the dry-salted fish. Above 86° F. sufficient brine to cover the fish was formed from the dry salt in 15 hours. About 30 hours were required for the lots at 70 and 63° F. to form enough brine to cover all the fish. The lots at 75.5 and 80° F. formed sufficient brine to cover the fish in somewhat less time. The gradual increase in the amino-acid content of the brines of the brine-salted fish (S) was probably due to the slow diffusion out of the water containing the amino acids dissolved in it. The immediate rise of the amino-acid titration value to about 4.5 c. c. in the dry-salt method was probably due to the rapid movement outward of the water in the fish.

When the amino-acid titration values rose above 9 c. c. in the dry-salted lots, the fish (D) were found to be spoiled. This was observed in five days at 93° F. and in seven days at 87° F. The lot at 80° F. did not spoil in this case.

In the case of those fish salted in brine (S) when the formol-titration value rose to 5 c. c. N/10 alkali, the fish were observed to be spoiled. This was noted at five days for those at 93° F.; at seven days for those at 87° F.; and at nine days for those at 80° F.

TABLE 7.—VOLUMES OF BRINE FORMED DURING SALTING.

[Lots D refer to samples dry salted; lots S, to those brine salted.]

Lot.	Weight of fish.	Volume.	Lot.	Weight of fish.	Volume.
	Kg.	*C. c.*		*Kg.*	*C. c.*
2D	2.6	770	5D	2.6	780
2S	1.3	1,580	5S	1.3	1,625
3D	2.6	815	6D	2.6	850
3S	1.3	1,610	6S	1.3	1,670
4D	2.6	820	7D	2.6	680
4S	1.3	1,670	7S	1.3	1,620

The figures in Table 6, together with the volumes of the brine given in Table 7, were used to calculate the total amounts of amino-acid nitrogen formed in the brines. These figures are given in Table 8.

TABLE 8.—TOTAL AMOUNT OF AMINO-ACID NITROGEN FORMED IN BRINES.

[Lots D refer to samples dry salted; lots S, to those brine salted.]

Lot.	Total amount amino nitrogen after—					Temperature.
	19 hours.	67 hours.	5 days.	7 days.	9 days.	
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*°F.*
2 D	0.203	0.215	0.220	0.220	0.311	63
2 S	.115	.168	.176	.238	.304	63
3 D	.217	.224	.254	.250	.328	70
3 S	.130	.215	.205	.247	.380	70
4 D	.201	.238	.259	.270	.349	75.5
4 S	.133	.242	.233	.298	.412	75.5
5 D	.192	.222	.310	.367	.412	80
5 S	.112	.246	.273	.392	.498	80
6 D	.197	.230	.414	.505	.532	87
6 S	.126	.317	.345	.488	.677	87
7 D	.168	.273	.392	.499	.614	93
7 S	.104	.310	.417	.602	.867	93

In order to make the figures in Table 8 comparable, the total amounts of amino-acid nitrogen formed were divided by the weights of fish salted in the different lots. These figures are presented in Table 9.

TABLE 9.—AMOUNT OF AMINO-ACID NITROGEN FORMED IN BRINE PER KILOGRAM OF FISH.

[Lots D refer to samples dry salted; lots S, to those brine salted.]

Lot.	Amino-acid nitrogen per kilogram of fish after—					Temperature.
	19 hours.	67 hours.	5 days.	7 days.	9 days.	
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	°F.
2 D	0.078	0.083	0.085	0.085	0.119	63
2 S	.089	.129	.135	.183	.234	63
3 D	.084	.086	.098	.097	.126	70
3 S	.100	.165	.158	.190	.292	70
4 D	.077	.092	.099	.104	.134	75.5
4 S	.102	.186	.179	.228	.316	75.5
5 D	.074	.086	.119	.141	.158	80
5 S	.086	.189	.210	.300	.383	80
6 D	.076	.089	.159	.195	.208	87
6 S	.097	.244	.266	.377	.510	87
7 D	.065	.105	.151	.193	.236	93
7 S	.080	.238	.320	.465	.666	93

At the end of the experiment samples from each lot were cooked. All the fish salted at 87 and 93° F. were spoiled. About 20 per cent of the fish salted in brine at 80° F. were spoiled. None of the fish salted by the dry-salt method at this temperature (80° F.) were spoiled. Fish salted with dry salt at 80° F. were eaten both by Prof. B. P. Livingston and the writer and were pronounced satisfactory. All fish salted at lower temperatures were in good condition. The results of the cooking trials check with the amount of decomposition, as shown by the total amount of amino acids formed in Table 10.

A composite sample of the fresh squeteague gave on analysis 0.022 per cent amino-acid nitrogen. This figure was found to be fairly constant for squeteagues but was higher when the samples had been iced for a long period.

In Table 10 the various amounts of amino-acid nitrogen formed in the brine, fish, and salt are given; also the total amino-acid nitrogen formed and the total amount of amino-acid nitrogen formed per kilogram of fish is given.

TABLE 10.—TOTAL AMOUNT OF AMINO-ACID NITROGEN FORMED DURING SALTING PERIOD.[a]

[Lots D refer to samples dry salted; lots S, to those brine salted.]

Lot.	Amount of salt used.	Amount of brine used.	Average temperature of salting period.	Weight of fresh fish.	Amino-acid nitrogen in fresh fish.	
	Grams.	C. c.	° F.	Grams.	Per cent.	Grams.
2 D	990	....	63	2,600	0.022	0.572
2 S	250	1,300	63	1,300	.022	.286
3 D	990	....	70	2,600	.022	.572
3 S	250	1,300	70	1,300	.022	.286
4 D	990	....	75.5	2,600	.022	.572
4 S	250	1,300	75.5	1,300	.022	.286
5 D	990	....	80	2,600	.022	.572
5 S	250	1,300	80	1,300	.022	.286
6 D	990	....	87	2,600	.022	.512
6 S	250	1,300	87	1,300	.022	.286
7 D	990	....	93	2,600	.022	.572
7 S	250	1,300	93	1,300	.022	.286

Lot.	Total amino-acid nitrogen at end in— Fish.	Brine.	Salt.	Fish, brine, and salt.	Amino-acid nitrogen formed. Total.	Per kilogram fresh fish.	Increase over dry-salt method.	Physical condition of salted fish.
	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Per cent.	
2 D	0.660	0.311	0.056	1.027	0.455	0.175	....	Good.
2 S	.333	.304	.000	.637	.351	.270	54	Do.
3 D	.675	.328	.065	1.068	.496	.190	....	Do.
3 S	.285	.380	.000	.665	.379	.292	54	Do.
4 D	.783	.349	.053	1.185	.613	.236	....	Fair.
4 S	.332	.412	.000	.744	.458	.352	49	Do.
5 D	[b].934	.412	.078	1.424	.854	.328	....	Do.
5 S	[b].451	.498	.000	.949	.663	.510	55	Spoiled.
6 D	[b]1.276	.532	.068	1.896	1.324	.510	....	Do.
6 S	[b].594	.677	.000	1.271	.985	.756	48	Do.
7 D	[b]1.492	.614	.096	2.202	1.630	.628	....	Do.
7 S	[b].610	.867	.000	1.477	1.191	.916	45	Do.

[a] In this experiment the fish were cleaned after two days' icing by removing the heads, eviscerating, and washing carefully, and were salted for nine days.

[b] Number is slightly high because of the accidental discard of the sample by one of the writer's coworkers. The result given is from sample taken three days after the fish had been removed from the constant-temperature compartments. The fish were kept at 64.5° F. during those three days. However, any slight error would be the same for all samples.

These figures show that the total amounts of amino-acid nitrogen formed are much greater in the case of the brine-salted fish. The increase varies from 48 to 55 per cent. This seems to prove that

the brine-salt method is not as efficient in preserving fish as the dry-salt method.

The writer wishes to point out the value of the amino-acid content of fish and brine as a criterion in estimating and detecting spoilage. Any two lots of the same fish may be compared and their relative freshness determined. This may be used for either fresh or salted fish. If the fish have been salted by the same process, this may be done quite easily by determining amino-acid nitrogen in the brines.

It also seems probable that the increase in amino-acid content could be used to forecast spoilage of fish during the salting period. A rapid rise in the amino-acid content of the brine would warn the salter that his fish were in danger of spoiling, and the salter could remove them to cold storage or use stronger brine.

RATE OF PENETRATION OF SALT.

In addition to following the formation of amino-acid nitrogen in fish salted by these two ways, the rate of penetration of chlorides into squeteagues was followed. This was accomplished in the same manner as the determination of the rates of penetration of different salts described on page 22.

METHOD.

The general procedure in these experiments was as follows: Fish of a uniform size (3.5 cm. thickness) were salted with pure sodium chloride by the two methods described on page 36. These two jars of fish were placed in a constant-temperature compartment and sampled at the end of 1, 4, 7, and 10 days. The temperature of the fish did not vary more than 1.44° from the average of 69.44° F. The samples were dried and ashed and the chlorine determined by titration with a silver-nitrate solution. The results are given in Table 11.

TABLE 11.—PENETRATION OF SALT INTO SQUETEAGUE, EXPRESSED IN TERMS OF PER CENT OF CHLORINE IN DRY SAMPLE, AT 70° F.

Method of salting.	Section of fish.	Per cent chlorine after— 1 day.	4 days.	7 days.	10 days.
Dry salted	Outer [a]	9.8	16.2	19.6	19.5
Do	Inner [b]	2.6	11.0	16.0	18.7
Brine salted	Outer [a]	8.4	15.3	17.3	17.8
Do	Inner [b]	1.8	8.3	12.2	15.7

[a] 0 to ½ cm. [b] ½ to 1 cm.

DISCUSSION.

The percentage of salt in both sections is higher throughout in the case of the dry-salted fish than in the brine-salted fish. This shows that the salt penetrated more rapidly in the case of the dry-salt method. More data could be given which verify the results of this experiment.

This work agrees with the results obtained by the estimation of the rate of amino-acid formation. For, when the salt penetrates

more rapidly, as in the case of the dry-salt method, less amino acids are formed than when the salt penetrates more slowly. However, the retardation of the rate of penetration is less marked. This suggests the possibility that small differences in salt content of fish may be responsible for much greater differences in the rate of decomposition of the fish.

Figure 5 illustrates graphically the data given in Table 11. It should be noted that the difference in chlorine content gradually increases.

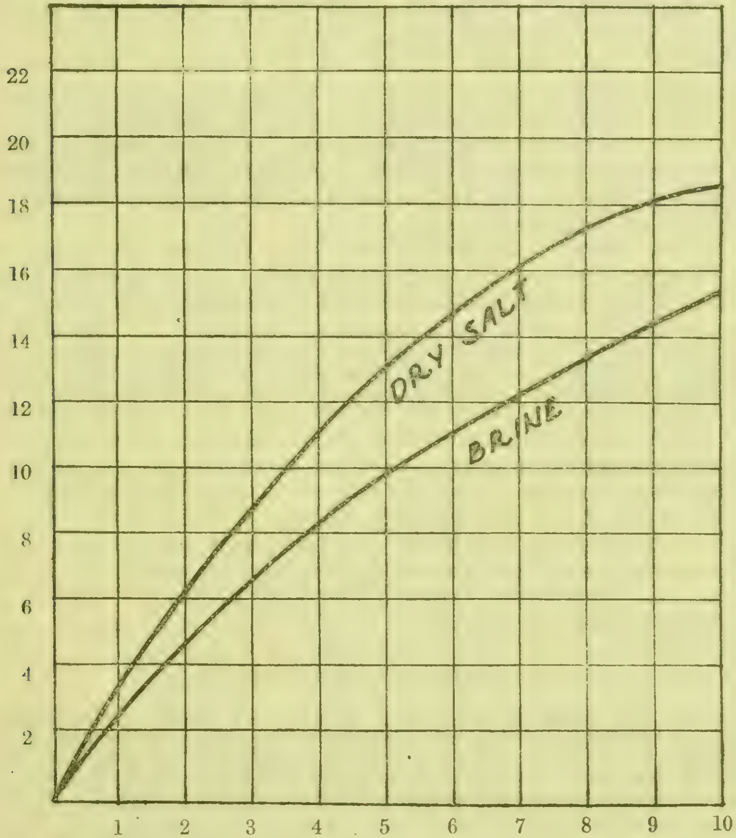

FIG. 5.—Curves show comparative rates of penetration of salt into fish when dry salted and when brine salted (section one-half to 1 cm. depth). Figures at left indicate per cent of chloride in dry fish; at bottom, time in days.

DISCUSSION.

PHYSICAL DIFFERENCES BETWEEN THE PRODUCTS OF THE TWO METHODS.

Dry-salted fish are invariably harder than brine-salted fish. This is probably due to the difference in moisture content. Brine-salted fish are about 7 per cent higher in moisture than dry-salted fish at the end of a salting period of 10 days. Dealers who "tight pack" their fish state that dry-salted fish require very little draining, whereas the brine-salted fish must be drained and dried for at least four days.

Dry-salted fish have a shriveled appearance, due to their drier condition. They are also brighter in appearance, as a less number of scales have been knocked off.

HYPOTHESIS TO ACCOUNT FOR RESULTS.

There are three important means of preserving foodstuffs, namely: 1. By destruction of bacteria and enzymes, which is accomplished by sterilization with heat. 2. By desiccation, or removal of water; bacteria do not thrive, nor are enzymes active in the absence of water. 3. By the addition of a preservative, which inhibits the growth of bacteria and the action of enzymes.

When fish are preserved by salting, we make use of the two last-mentioned means of preservation. The salt not only penetrates the fish but also dissolves and removes water. In some way dry salt removed more water from fish than brine. In the case of the dry-salt method the salt content of the fish is greater. The lesser decomposition taking place during dry salting than during brine salting is evidently due to these two facts.

It is not clearly understood just why the salt penetrates more rapidly when the dry-salt method is used. After stirring a vat of fish which are being brine-salted, the concentration of the upper layers of pickle immediately begins to decrease. It decreases most rapidly just after the fish are put in. In large vats of fish, the pickle sometimes becomes as weak as 60° (60 per cent saturation), even though there may be solid salt in the vat. Of course, this diluted brine is not so active as saturated brine. Also, it may happen that, although the pickle appears saturated according to the hydrometer reading, that in contact with the fish is not saturated, for water continually comes out of the fish and dilutes the brine in the vicinity of the fish. It would be well to try an experiment comparing the brine-salting method with the dry-salt method and have both brines stirred continually. The writer believes that both methods would show up equally well in such a test.

DRY-SALT METHOD MORE ECONOMICAL.

The dry-salt method involves a little more work at the beginning of the salting period; for more labor is involved in thoroughly distributing the salt throughout a large quantity of fish than is required to make up a brine and put the fish and salt into it. But after packing the fish into butts with dry salt, no further labor is required; whereas, brine-salted fish must be "roused" (stirred up), and salt must be added every day during the salting period. "Rousing" is an operation that requires considerable time and labor, and since the fish must be roused eight or nine times, the total labor expended in this process is large. There is no reason, therefore, for the brining of fish in order to save labor, as in the long run this process is not economical in respect to labor.

At present the used pickle from both processes is thrown away. It is the custom to save the surplus salt used in the dry-salt method. A great deal more pickle is left at the end in the brine method. This involves a greater loss of salt, when it is discarded, than when the smaller amount of dry-salt pickle is thrown away. The dry-salt

method is, therefore, more economical in regard to salt, as well as to labor.

SUMMARY.

1. The formation of amino-acid nitrogen was followed in the brine during the salting of fish by two methods—salting by use of dry salts and salting by use of brine.
2. The total amount of amino-acid nitrogen formed during salting was calculated.
3. More amino acid was formed by the brine method of salting.
4. The estimation of the amino-acid nitrogen content of fish and brine was suggested as a means of detecting and also forecasting spoilage.
5. The rate of penetration of salt into the squeteague when salted with dry salt and when salted with brine was determined. Salt applied dry goes into the fish more rapidly.
6. Samples of the fish salted by the two methods under consideration were cooked. It was found that all of the fish salted with dry salt at 80° F. were edible. Those salted with brine were unfit for consumption.
7. The dry-salt method was found to be more economical both of labor and salt.

These results show that the dry-salt method of salting fish, as practiced commercially, is much more efficient in preserving fish than the brine method. The dry-salt method is also the more economical of the two.

III. INFLUENCE OF METHOD OF CLEANING FISH FOR SALTING.

INTRODUCTION.

IMPORTANCE OF METHOD OF CLEANING.

It has always been known that the method of cleaning a fish preparatory for salting has an important influence on the quality of the product. From the first the writer noted that the salt penetrated more rapidly through the cut flesh of fish than through a surface covered with skin. This was first noticed while following the penetration into the fish of salt containing calcium chloride. The calcium chloride produced a marked whitening of the tissue. This was observed to proceed more rapidly on the cut side of the fish than on the side covered with skin.

The common practice in rating the quality of a salted herring or alewife is to break the fish open so that the backbone is exposed. The odor of the dark red or brown spots is then observed. The experienced fish salter knows that these spots are the first parts of the fish to spoil. They are caused by the coagulation and partial decomposition of the blood. Most fish salters seem to realize that the blood is the most unstable substance contained in fish, for they rate the efficiency of different procedures in fish salting by the amount of blood that the processes "draw out." They are well aware of the fact that round fish can not be salted at as high a temperature as cut fish. Numerous fishermen have advised the writer that very little

trouble would be encountered in salting any fish if care would be taken to scrape the blood away from the backbone and then wash all the blood out of the fish.

These and other similar observations showed the importance of the mode of cleaning as a factor in fish salting. A series of experiments was, therefore, carried out for the purpose of learning which method of preparing fish for salting was the best.

COMMERCIAL METHODS OF CLEANING.

Uncut fish.—Large quantities of herring and alewives are annually salted round, or without cutting. Some of these are washed, but other fish salters do not wash their round fish.

Pipping.—When herring are salted by the Scotch method, they are pipped or gibbed. This involves the cutting of the fish at the throat so that the gills and viscera are all removed, with the exception of the milt and roe. The head is not cut off. When fish are cut in this way it is difficult to remove the blood contained in the abdominal cavity.

Beheading.—"Headless roe" fish are prepared by partially cutting off the head of a roe fish, usually river herring; then the head is pulled off in such a way that the viscera, with the exception of the roe, are pulled out. Little blood may be washed out from fish cleaned in this manner. In some cases this procedure is altered by cutting the fish down the belly in addition to beheading.

Cutting.—The greater proportion of the river herring are salted after the heads and bellies have been cut off. In most cases this is done by the cutter in one operation.

Cutting and scraping.—In some vicinities small quantities of river herring are salted after being cleaned perfectly. The heads and bellies are cut off, and then the abdominal cavity is scraped until all the blood under the backbone and all the membranes are removed. Fish cleaned in this way are usually consumed locally.

Splitting.—Larger fish, such as the mackerel, cod, haddock, cusk, and the like, are usually eviscerated and split. This is considered essential for proper salting.

EFFECT OF CLEANING ON PROTEIN DECOMPOSITION.

METHOD.

The work on cleaning was done on the river herring. Two hundred and fifty pounds of river herring were purchased from a local Albemarle Sound fisherman. These fish were iced as soon as they were received from the boat, which was about two hours after their capture. The fish were divided into 8 lots: 2 lots of 1,000 grams each were salted round; 2 other lots were pipped; 2 lots were cleaned by cutting off the heads, cutting the fish the length of the belly, and removing the entrails, with the exception of the milt and roe; and 2 lots were cleaned by cutting and scraping. The heads and viscera were removed, including the milt and roe. These fish were then well washed, and blood and membranes were scraped out of the abdominal cavity. Great care was taken in this case to remove all visible

blood, including that underneath the backbone. All the lots were then weighed out. Exactly 1,000 grams of cleaned fish were taken in each case. They were salted in dry Diamond Flake salt, which is a fine, pure, granulated salt. Three and a third kilograms of salt were used on each lot during the first packing. The following day 833 grams of salt were added to each lot of fish.

One lot cleaned in each way was placed in each of two constant-temperature compartments, which have been previously described. One of these constant-temperature compartments was regulated for 79° F. The other was set for 88° F. Both these temperatures, it will be noted, are very high for salting fish. The results of these experiments are given in Table 12.

TABLE 12.—DEVELOPMENT OF AMINO-ACID NITROGEN IN FISH CLEANED IN VARIOUS WAYS.[a]

Experiment No.	Method of cleaning.	Average temperature of salting period.	Weight of fresh fish.	Amino-acid nitrogen in fresh fish (4 hours).	
		° F.	Grams.	Per cent.	Grams.
BA-1	No cleaning; salted round	79	1,000	0.029	2.90
BA-2	Pipped	79	1,000	.027	2.70
BA-3	Head cut off; abdominal cavity split open; viscera removed, with exception of milt and roe.	79	1,000	.022	2.20
BA-4	Cleaned perfectly; milt and roe removed	79	1,000	.020	2.00
BA-5	No cleaning; salted round	88	1,000	.029	2.90
BA-6	Pipped	88	1,000	.027	2.70
BA-7	Head cut off; abdominal cavity split open; viscera removed, with exception of milt and roe.	88	1,000	.022	2.20
BA-8	Cleaned perfectly; milt and roe removed	88	1,000	.020	2.00

Experiment No.	Total amino-acid nitrogen at end in—				Amino-acid nitrogen formed.		Physical condition of fish.
	Fish.	Brine.	Salt.	Fish, brine, and salt.	Total.	Per kilogram fresh fish.	
	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	
BA-1	7.88	2.52	0.22	10.62	7.72	0.77	Badly spoiled; bloated.
BA-2	6.66	2.09	.29	9.04	6.34	.63	Spoiled.
BA-3	6.80	2.06	.19	9.05	6.85	.68	Do.
BA-4	3.83	1.70	.13	5.66	3.66	.37	Excellent condition.
BA-5	10.70	3.08	.35	14.13	11.23	1.12	Badly spoiled; bloated.
BA-6	7.75	2.40	.20	10.35	7.65	.76	Badly spoiled.
BA-7	7.72	2.45	.22	10.39	8.19	.82	Do.
BA-8	4.60	1.95	.14	6.69	4.69	.47	Excellent condition.

[a] In this experiment the fish were dry salted for nine days, four hours after capture, with 4.166 kilograms of Diamond Flake salt (99.78 per cent NaCl).

DISCUSSION.

The remarkable thing about this experiment is that all the fish salted were entirely spoiled except those cleaned perfectly. Even the lot of perfectly cleaned fish which was salted at a temperature of 88° F. throughout the salting period was found to be in perfect condition at the end. These fish were cooked and sampled by six persons. All pronounced them to be far superior to the commercial salt-fish product. One critic went so far as to say that they were on a par with the fresh river herring.

The results of the chemical analyses for amino-acid nitrogen in the various samples verifies these observations. Both perfectly cleaned lots ran very low in amino acids. This shows definitely that there was very little protein decomposition.

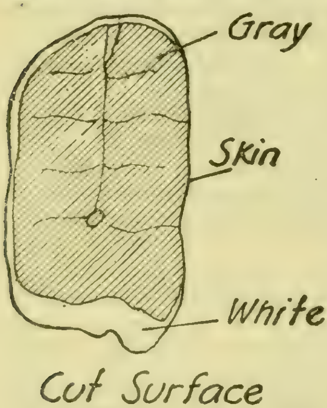

FIG. 6.—Whitening of fish after 1 day in brine.

The results given in Table 12 show that round fish spoil very easily when salted. This is a very poor way to salt fish unless the weather is very cold. On comparing BA–2 with BA–3, and BA–6 with BA–7, the writer is forced to the conclusion that it makes very little difference whether the fish are cut the length of the belly or not. It may be that those cut open, BA–3 and BA–7, were infected with bacteria during the process. At these high temperatures bacteria seem to thrive even in the presence of the salt. This was evidenced by the bloating of all the round fish, due to the accumulation of gas in the belly. This also took place in some of the pipped fish.

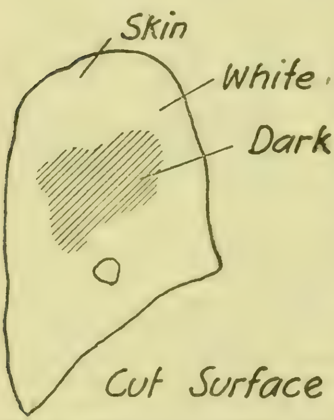

FIG. 7.—Whitening of fish after 6 days in brine.

The writer wishes to point out that the only difference between lots BA–3 and BA–4 and between lots BA–7 and BA–8 was that BA–3 and BA–7 contained milt, roe, and blood. These substances were, then, alone responsible for the spoilage. No other factor could be the cause, as the procedure in handling was the same in every respect. The question then arises as to which caused the spoilage—the blood, roe, or milt.

Previously a similar experiment had been attempted, except that the work was carried out in a commercial plant and was merely qualitative. This experiment was not quite so successful, for at a lower temperature, 80° F., some of the fish spoiled. However, the majority were in excellent condition. Upon examination, the spoiled fish revealed that the work of removal of blood before salting had been carelessly done, for blood was found under the backbone, above the vent, in every spoiled fish. None of the good fish showed traces of blood. Unfortunately, no attempt was made to salt milt and roe at high tem-

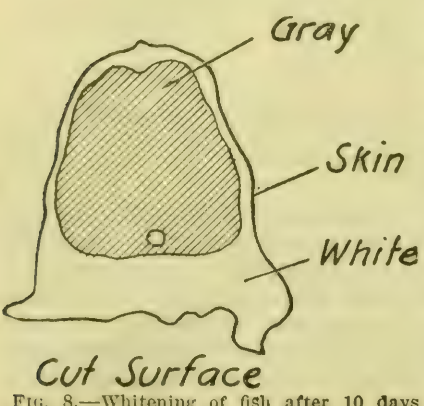

FIG. 8.—Whitening of fish after 10 days in brine.

peratures. Such experiments would show whether these substances are partially responsible for the spoilage. However, both the milt and roe must be removed if all of the blood be taken out of the fish. This is, therefore, a point of secondary importance.

ACTION OF THE SKIN.

METHOD.

The skin of fish is known to be a membrane which is more or less impermeable to the passage of dissolved salts. In the work on penetration of different salts it was noted that the penetration of salt into the fish took place much more rapidly through the cut flesh than through fish covered with skin. In the experiments on the penetration of salts containing calcium salts as impurity the passage of the salt into the fish could be followed very easily, for as the salt passed into the fish the fish became very white. This gave an easy way of estimating the rate of penetration of the salt into the different parts of the fish. The fish were cut on different days. The depth of the whitening was measured and the cross sections were drawn to scale. The diagrams are given to show how much more rapid the penetration of the salt is through the cut surface than through the skin surface.

Figure 6 shows the appearance of a cross section of a squeteague after it had been in salt for one day. The whitening had penetrated 5 mm. on the cut surface, but the whitened condition was found only 1 mm. under the skin. Figure 7 shows a cross section of the fish after it had been salted for six days. At this time the line between the light and dark portions of the section was not so distinct. Figure 8 shows a section of the fish near the end of the salting period, which was 10 days. There is yet a portion of the fish which was not white. This shows that the fish as yet was not salted uniformly throughout. The fish became entirely white throughout on the thirteenth day.

In order to gain a more accurate idea of the retardation of the penetration of the skin by the salt, some experiments were tried to determine the relative rate of penetration of salt into skinned and unskinned fish. In these experiments both skinned and unskinned squeteagues were salted in dry salt by the ordinary procedure, as described previously. The salt used contained 1 per cent of calcium chloride. This is about the purity of the average salt used for the salting of fish.

The penetration of the chlorides into the fish was determined by analyzing different sections of the fish from day to day. The procedure followed has been described in the first part of this paper. The results of the analyses of the sections from one-half centimeter to 1 cm. in depth are given in Table 13.

TABLE 13.—COMPARATIVE RATE OF PENETRATION OF CHLORIDES[a] INTO SKINNED AND UNSKINNED FISH,[b] EXPRESSED IN PER CENT OF CHLORINE IN DRY FISH.

Mode of cleaning.	Per cent chlorine after—			
	22 hours.	4 days.	7 days.	13 days.
Skinned	9.7	19.8	20.2	20.3
Unskinned	1.7	11.9	18.9	20.3

[a] Analysis of salt used, 99 per cent sodium chloride, 1 per cent calcium chloride.
[b] Inner section of fish, ½ to 1 cm.

DISCUSSION.

These data show that salt penetrates skinned fish at approximately double the speed it enters unskinned fish. Therefore, skinned fish may be salted in about one-half the time required for unskinned fish. Of course, it is not practical to skin most fish before salting; but these results show the great advantage gained in splitting a fish wherever this procedure may be followed. In hot climates the length of the salting period, the period of danger, may be cut in two.

St. Johns River shad are successfully salted in Florida by the present methods. Attempts at salting St. Johns River alewives have repeatedly failed. The reason for the successful salting of the shad may be because the shad are split and washed before salting. The alewives are salted without splitting. Due to this splitting, the salting period of the shad may be shorter than the salting period for the alewives.

PRACTICAL APPLICATIONS.

This work on the methods of cleaning proves beyond doubt that the chief cause of spoilage of fish during salting in hot weather is the decomposition of the blood contained in the fish. This seems to show that the problem of salting fish in warm climates is in reality a very simple one.

What must be done, then, in order to salt the alewives of the Florida rivers successfully during warm weather? The only change from the North Carolina method necessary is that greater care must be taken to remove every bit of blood and viscera. This can be accomplished if the roe and buckroe are removed in the cleaning operation. These may be canned profitably. After cleaning, the under side of the backbone should be scraped so that all the blood and membranes in the abdominal cavity are removed. A 20-penny nail is an instrument that can be conveniently used for scraping the backbone. The head of the nail may be ground thinner on an emery wheel. This operation sharpens the head so that it cuts out the membranes without much pressure. A single operator can easily scrape out a thousand fish in an hour. After scraping the fish they should be soaked in cold water for at least one-half hour. This dissolves practically every trace of the blood. It is good practice to wash the fish in a false-bottomed wheelbarrow with a powerful stream of water. After soaking the fish they should be packed in dry salt.

The above method of cleaning fish pays, even though the salting is done in a climate where this procedure is not essential; for extra washing and cleaning produces fish of much finer quality than those produced by the old methods. The up-to-date canner is using every possible precaution to avoid the presence of blood in his canned fish, so as to produce an entirely white fish. The well-washed fish when salted does not undergo a discoloration due to the presence of blood. The strong taste of salted river herring is eliminated in the washing.

Perfectly cleaned fish, salted at high temperatures, should bring a better price than the old dirty-looking product produced in the North. The public would soon learn of their improved quality.

All large fish salted in warm weather should be split, and care should be taken to remove the blood. This should be less difficult in

the case of the split fish, for the blood would be almost entirely exposed to view. The splitting would also greatly decrease the length of the salting period, due to the more rapid penetration of the salt.

SUMMARY.

River herring, cleaned by various methods, were salted at very high temperatures. All save those from which all roe, milt, and blood had been removed spoiled. Perfectly cleaned river herring were salted at a temperature of 88° F. It was concluded, therefore, that the chief cause of spoilage of fish during salting is the decomposition of the blood remaining in the fish. The rate of penetration of salts into skinned fish was compared with the rate of penetration of salt into fish before skinning. It was found that salt penetrates skinned fish at about double the speed it enters unskinned fish. This proves the great value of splitting fish preparatory to salting. These results are of great value in a practical way, for they show that if proper care be taken in the cleaning of fish, it is probable that they may be salted in any hot weather anywhere in the United States. With only an hour's extra work per thousand of river herring, these fish may be prepared for salting in hot weather. The salt-fish product prepared by this extra care in cleaning is of much better quality than the commercial salt fish.

IV. INFLUENCE OF FRESHNESS IN SALTING FISH.

INTRODUCTION.

Staleness in fish is undesirable. However, more or less staleness is always unavoidable. It seems reasonable to suppose that during colder weather staler fish may be salted than during hot weather. Few data in the literature concerning the limits of freshness are of value, for there are no standard methods of judging staleness. Most writers on the subject have used various physical criteria to estimate the relative freshness of stale fish. Some of the physical qualities that have been used as criteria are: 1. The presence, or absence, of a reddish discoloration on the ventral aspect of the backbone. 2. The odor. 3. The manner in which the flesh separates from the backbone. 4. The appearance of the abdominal walls.

The use of such criteria leaves too much to the judgment of the investigator. In other words, the personal equation plays too prominent a part. There are really but two ways of fairly stating the degree of freshness of any fish. The first and most accurate way is to give the number of hours since the fish was caught and the temperature at which it has stood for that time; the other is to state its chemical analysis. The per cents of amino-acid nitrogen and of ammoniacal nitrogen are particularly indicative of the condition of the fish.

In experiments previously described the number of hours the fish had been out of the water before they were salted has been given wherever possible. Since it was impossible to obtain live fish, standard freshness was considered as a fish transported in a boat at atmospheric temperature for two hours. Then the fish were iced and

cleaned, and after being iced for two hours were salted. There was, of course, the error caused by the difference in temperatures of different days. However, since at no time was the atmospheric temperature above 80° F., little decomposition took place in the two hours.

Since fish spoil so quickly during hot weather, an attempt was made to find out how fresh they must be in order successfully to salt them at various temperatures. This should show whether the cause of spoilage during salting in hot weather was through the use of stale fish.

Insufficient work has been accomplished to obtain any very definite data concerning the necessary freshness of fish for salting. Unfortunately, the work was carried out at too high temperatures, and all of the stale lots of fish spoiled.

METHOD.

Eighty pounds of glut herring (*Pomolobus æstivalis*) were obtained after they had been out of the water for four hours. During this time they had been kept at approximately 60° F. They were divided into five lots and kept at 64° F. One lot was immediately cleaned, washed, and dry salted according to the usual method. After 16 hours a second lot was cleaned, washed, and salted; and after 24 hours a third lot was cleaned, washed, and salted. The first three lots were cleaned by beheading and eviscerating the fish, without removing the milt and roe. After 33 hours the two remaining lots were cleaned and salted. One of these lots was cleaned in the same manner as that of the first three. The other was cleaned more perfectly. The milt and roe were taken out, and the blood was scraped out from under the backbone. These fish were given an extra washing.

The five lots of fish were allowed to stand 15 days (from day of catch) before the analyses were made. For this reason the amounts of amino acids found were higher than in comparative lots which were analyzed at the end of nine days. The total amounts of amino-acid nitrogen formed were computed as before. The results are given in Table 14.

TABLE 14.—DEVELOPMENT OF AMINO-ACID NITROGEN IN FRESH AND STALE FISH AT 64° F.[a]

Experiment No.	Time between capture and salting.	Method of cleaning.	Weight of fresh fish.	Amino-acid nitrogen in fresh fish.	
	Hours.		*Grams.*	*Per cent.*	*Grams.*
Z-1	4	Head and viscera removed, with the exception of the milt and roe; washed once in ice water.	6,000	0.022	1.32
Z-2	20	do	6,000	.022	1.32
Z-3	28	do	6,000	.022	1.32
Z-4	35	do	5,500	.022	1.21
Z-5	35	Head, blood, and all viscera removed; washed twice in ice water.	5,500	.020	1.10

[a] In this experiment the fish were dry salted for 15 days with 2,200 grams of chemically pure sodium chloride.

TABLE 14.—DEVELOPMENT OF AMINO-ACID NITROGEN IN FRESH AND STALE FISH AT 64° F.—Continued.

Experiment No.	Total amino-acid at end in—				Amino-acid formed.		Physical condition of fish.
	Fish.	Brine.	Salt.	Fish, brine, and salt.	Total.	Per kilogram fresh fish.	
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	
Z-1	5.06	1.19	0.51	6.76	5.44	0.91	Good.
Z-2	7.28	1.51	.43	9.22	7.90	1.32	Tainted.
Z-3	7.86	1.53	.44	9.83	8.51	1.42	Spoiled.
Z-4	8.54	1.60	.40	10.54	9.33	1.70	Badly spoiled.
Z-5	4.54	1.51	.30	6.35	5.25	.95	Tainted.

DISCUSSION.

Sixty-four degrees Fahrenheit is very close to the maximum temperature for salting fish containing blood, milt, and roe. For this reason all the stale fish spoiled. However, a comparison of the results obtained in lots Z-4 and Z-5 shows quite plainly that the roe, milt, and blood are the first portions of a fish to spoil at lower temperatures. This suggests a method of dealing with all stale fish. Evidently much staler fish may be salted if they are perfectly cleaned than if they contain blood, milt, or roe.

Two other experiments at higher temperatures were tried which verify these results. The other experiments were conducted at 75 and 79° F., respectively, which temperatures were so high that all the fish spoiled. These experiments were almost exact duplicates of the experiments reported in Table 14; hence they will not be described in detail. The fish were cleaned and salted at 4, 10, 14, and 28 hour intervals. Four lots of fish were kept at 75° and four at 79° during this period. The 4, 10, and 14 hour lots were only partially cleaned, the roe, milt, and blood being left in and the fish washed but once. The 28-hour lots were cleaned perfectly, the roe and milt being removed and the blood scraped out. Lot Z-5 was treated in the same way. All of these lots were salted in brine. The results of the calculations of the total amounts of amino-acid nitrogen formed are given in Table 15.

TABLE 15.—DEVELOPMENT OF AMINO-ACID NITROGEN IN FRESH AND STALE FISH AT 75 AND 79° F.[a]

Experiment No.	Time between capture and salting.	Method of cleaning.	Average temperature of salting period.	Weight of fresh fish.	Amino-acid nitrogen in fresh fish (4 hours).	
	Hours.		*°F.*	*Grams.*	*Per cent.*	*Grams.*
DA-8	4	Head and viscera removed with exception of milt and roe. Washed once in ice water.	75	5,000	0.022	1.10
DA-11	10	.....do	75	5,000	.022	1.10
DA-12	14	.....do	75	5,000	.022	1.10
DA-14	28	Head and all viscera removed. Blood washed out.	75	5,000	.020	1.00
DA-1	4	Head and viscera removed with exception of milt and roe. Washed once in ice water.	79	5,000	.022	1.10
DA-4	10	.....do	79	5,000	.022	1.10
DA-5	14	.....do	79	5,000	.022	1.10
DA-7	28	Head and viscera removed. Blood washed out.	79	5,000	.020	1.00

[a] In this experiment the fish were salted for nine days in 5 liters of brine prepared from Diamond Flake salt (NaCl 99.78 per cent) and 1 kilogram of this salt.

TABLE 15.—DEVELOPMENT OF AMINO-ACID NITROGEN IN FRESH AND STALE FISH AT 75 AND 79° F.—Continued.

Experiment No.	Total amino-acid nitrogen at end in—			Amino-acid nitrogen formed.		Physical condition of fish.
	Fish.	Brine.	Fish, brine, and salt.	Total.	Per kilogram fresh fish.	
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	
DA-8	2.46	2.09	4.55	3.45	0.69	Tainted.
DA-11	3.50	2.11	5.61	4.51	.90	Spoiled.
DA-12	3.36	2.45	5.81	4.71	.94	Do.
DA-14	2.15	2.51	4.66	3.66	.73	Tainted.
DA-1	3.00	2.00	5.00	3.90	.78	Spoiled.
DA-4	3.43	2.56	5.99	4.89	.98	Do.
DA-5	3.64	2.71	6.35	5.25	1.05	Badly spoiled.
DA-7	3.34	2.94	6.28	5.28	1.06	Spoiled.

Comparisons of the analyses of lot DA-12 with the analyses of lot DA-14 and of DA-5 with DA-7 show that thorough cleaning permits the salting of staler fish, for there was no more decomposition in the case of the thoroughly cleaned 28-hour fish than in the case of the 14-hour fish containing milt, blood, and roe. A comparison of DA-8 with DA-11 plainly indicates that at high temperatures great care must be taken to obtain absolutely fresh fish for salting. Evidently there is a temperature somewhere between 50 and 60° F., above which fish can not be kept for any length of time without spoiling.

GENERAL CONCLUSIONS.

I. *Influence of impurities in salt in salting fish.*—Calcium and magnesium salts and sulphates, as impurities in salt, retard the penetration of salt into fish. Salts containing these impurities, therefore, cause fish to spoil during salting at a lower temperature than salts not containing such impurities. Of these three impurities, calcium is the only one present in commercial salts in large enough quantities to have an appreciable effect on the quality of the salt.

II. *A comparison of the efficiency of brine and dry salt for salting fish.*—Fish packed in dry salt, without any addition of brine, may be kept at a higher temperature than fish salted in brine, for less decomposition takes place if no brine be added. The dry-salt method is the more economical method of the two.

III. *Influence of method of cleaning fish for salting.*—The removal of all blood and viscera, including roe and milt, is absolutely essential for the salting of fish at high temperatures. Blood spoils at a temperature at least 25° F. lower than the spoilage temperature of the flesh of fish.

IV. *Influence of freshness in salting fish.*—During warm weather freshness of fish is essential to successful salting. However, much staler fish may be salted if all blood, roe, and milt are removed in cleaning.

RELATIVE IMPORTANCE OF FACTORS.

The predominant factor in controlling the qualities of the salt-fish product and the maximum temperature of salting is the thorough cleaning of the fish, so as to effect the removal of all viscera and blood. If fish are perfectly cleaned, it appears possible to obtain a white, sweet-tasting salt fish at any American summer temperature. If the fish are not perfectly cleaned, it is impossible to salt them at any temperature averaging above 70° F. by any known method of salting, regardless of the kind of salt used or the mode of application of the salt.

The factor of second importance is freshness. When the temperature of the fish is above 70° F., the fish must be salted the same day that they are caught, if they are to be successfully cured. At lower temperatures this factor is of less importance, until at 32° F. this factor is practically eliminated. That is to say, at this temperature fish may be kept for long periods and yet be salted successfully.

Next in line of importance comes the method of application of salt. Fish iced for two days (see p. 36) may be salted at about 4° higher temperature by the application of dry salt rather than brine. Fine salt must be used for small fish.

Of next importance is the composition of the salt. This factor may be easily controlled by the purchase of salt of known purity. This affects the physical qualities of the salt fish. Commercial salts high in calcium lower the maximum temperature at which fish may be salted by any known method.

PRACTICAL APPLICATIONS OF RESULTS.

The probability that fresh fish may be salted without danger of spoilage in any climate in the United States is of considerable importance. The only requirements for salting fish at high summer temperatures are:

1. All viscera and blood must be removed in cleaning.
2. All large fish must be split.
3. The fish must be salted in a reasonably fresh condition.
4. No brine should be added in salting.
5. Salts low in calcium must be chosen.

These requirements do not involve great changes in the methods of salting now employed. In reality they merely require more perfect cleaning and greater care in the selection of salt. The fish of our southern waters that are as yet not utilized may be salted without any difficult changes in the present methods, and thus a great saving may be effected.

BIBLIOGRAPHY.

BENEDICT, S. R., and MURLIN, J. R.

1913. Note on the determination of amino-acid nitrogen in urine. The Journal of Biological Chemistry, Vol. XVI, No. 3, pp. 385–388. Baltimore.

BITTING, A. W.

1911. Preparation of the cod and other salt fish for the market: Including a bacteriological study of the causes of reddening. U. S. Department of Agriculture, Bureau of Chemistry Bulletin No. 133, 63 pp., 6 pls., 4 figs. Washington.

BRADLEY, H. C., and TAYLOR, JOSEPH.

1917. Studies of autolysis. V. The influence of bile on autolysis. The Journal of Biological Chemistry, Vol. XXIX, No. 1, pp. 281–288. Baltimore.

CLARK, E. D., and ALMY, L. H.

1918. A chemical study of food fishes. The analysis of 20 common food fishes, with especial reference to a seasonal variation in composition. The Journal of Biological Chemistry, Vol. XXXIII, No. 3, pp. 483–498. Baltimore.

HOAGLAND, RALPH, MCBRIDE, CHARLES N., and POWICK, WILMER C.

1917. Changes in fresh beef during cold storage above freezing. U. S. Department of Agriculture Bulletin No. 433, contribution from the Bureau of Animal Industry, 100 pp., 2 figs. Washington.

OTTOLENGHI, D.

1913. Studien Über die Reifung und Zersetzung des Fleisches. Zeitschrift für Untersuchung der Nahrungs- und Genussmittel, sowie der Gebrauchsgegenstände, Bd. XXVI, Heft 12, pp. 728–758, 6 figs. Berlin.

PHALEN, W. C.

1917. Technology of salt making in the United States. Department of the Interior, Bureau of Mines Bulletin 146, Mineral Technology 20, 149 pp., 24 pls., 10 figs. Washington.

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